



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification<sup>6</sup> :</b> <b>B60R 21/16</b>		<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 98/12075</b> <b>(43) International Publication Date:</b> 26 March 1998 (26.03.98)
<b>(21) International Application Number:</b> PCT/US97/16543		<b>(81) Designated States:</b> AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).	
<b>(22) International Filing Date:</b> 18 September 1997 (18.09.97)			
<b>(30) Priority Data:</b> 08/715,656 18 September 1996 (18.09.96) US			
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**(54) Title:** ADHESIVELY-BONDED INFLATABLE RESTRAINT AND METHOD OF MAKING**(57) Abstract**

An adhesively-bonded inflatable restraint and a method of making such a restraint are disclosed. The inflatable restraints of the present invention have a substantial portion of at least one structural beam bonded with an adhesive. An inflatable protection device which includes such an adhesively-bonded inflatable restraint is also disclosed.

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## ADHESIVELY-BONDED INFLATABLE RESTRAINT AND METHOD OF MAKING

### Field of the Invention

This invention relates to inflatable restraints such as, for example, those used in passenger vehicles, more particularly, to such restraints having seams that are adhesively bonded and, even more particularly to such restraints with seams having a lap-shear geometry that are adhesively-bonded.

### Background of the Invention

15 Current passenger vehicles are equipped with inflatable restraints. Examples of inflatable restraints include driver and passenger airbags, side impact bags, knee bolsters, head liner curtains, inflatable seat belts and the like. Recently, government regulations have forced automobile manufacturers to equip passenger cars and trucks with driver and passenger side airbags. Inflatable restraint systems 20 are complex and add significantly to the final cost of the automobile. In order to meet demand, size, and cost constraints, automobile manufactures continue to investigate ways to manufacture inflatable restraint systems more efficiently and to use materials that are lighter and have a lower cost.

Inflatable restraints such as, for example, airbags are commonly made 25 from woven nylon materials such as nylon 6 and nylon 6,6, or woven polyester materials such as polyethylene terephthalate. The fabric can be coated or uncoated. Commonly used coating materials are neoprene and more recently, silicone polymers. The coatings enhance the slip coefficient of the fabric so as to facilitate a smooth and rapid deployment, provide heat shielding and ablative protection to the 30 fabric from hot gases from the inflator, and prevent gases from escaping prematurely by sealing fabric pores. Inflatable restraints are usually inflated very rapidly, for example in about 10 to 55 milliseconds, at a pressure of from 5 to about 20 psi (34.5 to 138 kPa)

Airbags and other inflatable restraints are typically made by cutting patterns of material and then sewing the resulting pieces together. Dimensional tolerances are kept very tight and must be achieved with accuracy to very specific orientations. The threads used to sew the pieces together must also be of the proper fiber, 5 weight, construction, and have the proper coating for the application. The placement of the sewing patterns and stitches is also critical to the performance of the inflatable restraint. Typical sewn seams are formed by placing the two pieces of fabric on top of one another, with the edges aligned, and then stitching the pieces of material together at or near the edges. A sewn airbag is normally turned inside out 10 so that the sewn seams or the raw edges of the fabric are contained within the interior of the airbag, and thereby unseen.

One disadvantage of sewn seams having the above "conventional seam geometry" is that the manufacturing process for such pieces is labor intensive. Another disadvantage of stitched airbags is that during deployment of the airbag, 15 the stitches may cause the threads of the airbag fabric to stretch and form holes in the area stitched which can lead to leakage or deployment failure. This is known in the industry as "combing." Another disadvantage of sewn airbags is that the fabric used must be of a sufficient density yarn tenacity, or weight to prevent or minimize combing of the seams. Often, the weight of material needed for sewn seams 20 exceeds the weight needed to otherwise provide an effective inflatable restraint.

While attempts at addressing these disadvantages have been made, there is a continuing need for a relatively inexpensive inflatable restraint that overcomes the disadvantages associated with sewn seams while remaining reliable.

## 25 Summary of the Invention

The invention relates to an improved inflatable restraint in which at least one structural seam, and optionally other structural and nonstructural seams, as well as other portions of the restraint, are bonded or reinforced with an adhesive.

In one aspect of the present invention, an inflatable restraint is provided 30 which includes an inflatable chamber comprising at least one sheet of a material suitable for use in an inflatable restraint and one or more structural seams. Each

structural seam is formed by at least two sheet edges. The inflatable chamber has a substantial portion of at least one structural seam bonded with an adhesive selected such that the at least one structural seam is capable of withstanding inflation forces resulting from deployment of the inflatable restraint (i.e., the rapid inflation of the 5 inflatable chamber), when the structural seam is bonded with the adhesive.

It is desirable for the structural seam to have a lap shear geometry formed by two sheet edges overlapping each other so as to form overlapping sheet portions. The adhesive is disposed between the overlapping portions so as to bond the seam.

The adhesive, used according to the present invention, can be at least one 10 silicone pressure-sensitive adhesive comprising a silicone base polymer and a silicate (e.g., MQ) resin, where the silicone base polymer comprises condensation curable functional groups, and the silicate resin comprises condensation curable functional groups. The at least one silicone pressure-sensitive adhesive can be a condensation cured pressure-sensitive adhesive and/or a peroxide cured pressure-sensitive 15 adhesive, where the condensation cure pressure-sensitive adhesive further comprises a condensation curing agent and the peroxide cure pressure-sensitive adhesive further comprises a peroxide cross-linking agent. The condensation curing agent can be, for example, a condensation catalyst, a cross-linking agent, and/or a multifunctional cross-linking agent (e.g., an aminosilane) which serves as both 20 catalyst and cross-linker. It can be desirable for the silicone base polymer and the silicate resin to be pre-condensed together prior to the at least one silicone pressure-sensitive adhesive being applied and fully condensation cured. Pre-condensation of the pressure-sensitive adhesive can improve the shear strength and performance of the adhesive.

25 The adhesive, used according to the present invention, can be at least one addition-cure or hydrosilation cure silicone adhesive comprising an alkenyl functional silicone base polymer, a hydride functional cross-linking or chain extending agent (e.g., SiH), and a hydrosilation catalyst. The silicone base polymer has unsaturated (e.g., vinyl, propenyl, higher alkenyl, etc.) groups at its ends. It 30 may be desirable for a reinforcing agent to be included such as, for example, a silica, quartz, and/or MQ resin containing alkenyl or SiH functional groups. The

hydrosilation catalyst is typically a noble metal catalyst such as, for example, Pt and Rh. The at least one addition-cure silicone adhesive can be an addition-cure silicone pressure-sensitive adhesive or a room temperature vulcanizing adhesive.

The adhesive, used according to the present invention, can be at least one  
5 free radical-cure silicone pressure-sensitive adhesive comprising an ethylenically  
unsaturated silicone base polymer, and a silicate resin (e.g., MQ resin). The silicone  
base polymer has ethylenic unsaturation (e.g., acrylate, methacrylate, etc.) at its  
ends. The silicate resin is in sufficient quantity to provide the desired tack to the  
adhesive. It is desirable for a free radical catalyst to be included for initiating free  
10 radical polymerization, when the adhesive is to be thermal or thermal or radiation  
(e.g., UV or photo) cured. Optionally, a small percentage of a free radically  
polymerizable vinyl monomer can be included. In addition, a free radically  
polymerizable cross-linking agent may also be included.

The adhesive, used according to the present invention, can be at least one  
15 silicone adhesive comprising a non-curable tackified polydiorganosiloxane polyurea  
segmented copolymer. This at least one silicone adhesive can be selected from the  
group consisting of a pressure-sensitive adhesive (PSA), a heat activated pressure-  
sensitive adhesive (activated with heat and pressure), a non-tacky heat activated  
(e.g., hot-melt) adhesive and a combination thereof.

The adhesive, used according to the present invention, can be at least one  
20 silicone adhesive comprising a curable tackified polydiorganosiloxane oligourethane  
segmented copolymer. This at least one silicone adhesive can be selected from the  
group consisting of a pressure-sensitive adhesive, a heat activated pressure-sensitive  
adhesive, a non-tacky heat activated adhesive and a combination thereof. This at  
25 least one silicone adhesive can also be selected from the group consisting of a free-  
radical cure adhesive, a moisture cure adhesive and a combination thereof.

The adhesive, used according to the present invention, can be at least one  
moisture-cure room temperature vulcanizing silicone adhesive. This at least one  
silicone adhesive can be a neutral-cure room temperature vulcanizing adhesive.

30 In another aspect of the present invention, an inflatable protective device is  
provided which comprises a housing; an inflation device attached to the housing;

and an inflatable restraint. The inflatable restraint comprises an inflatable chamber having a substantial portion of at least one structural seam bonded with an adhesive so as to have a lap-shear geometry. The adhesive is selected such that the at least one structural seam is capable of withstanding inflation forces resulting from

5 deployment of the inflatable restraint, when the structural seam is bonded with the adhesive tape.

In a further aspect of the present invention, a method is provided for making an adhesive bonded inflatable restraint. The method comprises the steps of:

providing an adhesive and at least one sheet of a material suitable for use in an

10 inflatable restraint, with the sheet having two edges; overlapping the two edges of the sheet so as to form a seam having a lap shear geometry and to form at least part of an inflatable chamber; disposing the adhesive between the overlapping edges of the sheet; and activating the adhesive (by pressure and/or heat) so as to bond the overlapping edges together, wherein the adhesive is selected such that the seam is

15 capable of withstanding inflation forces resulting from deployment of the inflatable restraint, when the overlapping edges are bonded with the adhesive.

It can be desirable for the adhesive being provided to be a curable adhesive. In which case, the method includes the step of curing the adhesive after the step of activating the adhesive. The resulting seam will then, at least, be capable of

20 withstanding inflation forces resulting from deployment of the inflatable restraint, after the adhesive is substantially cured. With at least two sheets of a material, suitable for use in an inflatable restraint, being provided, each sheet can provide one of the edges used to form the seam.

It can be desirable for the step of disposing the adhesive between the

25 overlapping edges of the sheet to include bonding the adhesive along at least one of the edges before the step of overlapping the two edges of the sheet.

The present invention also relates to an improved inflatable restraint in which at least one structural seam, and optionally other structural and nonstructural seams, as well as other portions of the restraint, are adhesive bonded or reinforced

30 with an adhesive tape.

Accordingly, in an additional aspect of the present invention, an inflatable restraint is provided which comprises an inflatable chamber having a substantial portion of at least one structural seam bonded with an adhesive tape. The adhesive tape is selected such that each structural seam bonded with the adhesive tape is 5 capable of withstanding inflation forces resulting from the deployment of the inflatable restraint (i.e., the rapid inflation of the inflatable chamber).

The adhesive tape can comprise a backing having two major surfaces or sides and an adhesive on one major surface. In addition to the adhesive, the 10 backing is selected such that each structural seam bonded with the adhesive tape is capable of withstanding inflation forces resulting from the deployment of the inflatable restraint. The backed adhesive tape can be used in bonding a structural seam having a butt joint geometry.

The backing of the tape can be made from any suitable coated or uncoated (e.g., with silicone) materials which pass deployment and durability testing as 15 required for inflatable restraints, including suitable woven nylon fabrics, woven polyester fabrics, Kevlar®, Spectra®, films, nonwovens, including nonwoven fabrics, laminates of films, yarns and/or fibers, and the like.

The adhesive tape can, alternatively, be an adhesive transfer tape comprising one or more adhesive layers without a backing. It is desirable for such an adhesive 20 tape to be self-supportive, without a support backing, when used to bond a structural seam of the inflatable restraint. Such an adhesive tape can be used in bonding overlapping portions of a structural seam having an overlapping or lap shear geometry. The transfer tape can also be a double sided adhesive tape, with adhesive on both sides of a reinforcement backing.

25 It is desirable for the adhesive for the tape to be a hot melt-type adhesive. The adhesive may also be a pressure sensitive-type adhesive. In addition, the adhesive may exhibit a combination of the characteristics of a hot melt-type adhesive and a pressure sensitive-type adhesive. That is, the adhesive may need to have both heat and pressure applied in order to be sufficiently activated. It has also 30 been found desirable for the adhesive to comprise a silicone adhesive. It has been found more desirable for the adhesive to comprise a silicone adhesive containing a

silicone-urea segmented copolymer and even more desirable for a silicate resin (e.g., an MQ resin) to be included with the silicone-urea segmented copolymer. It is believed that other adhesives which provide the required performance, durability and processability could also be used to make an adhesive tape according to the 5 present invention. Other adhesives may include block co-polymer adhesives, acrylate adhesives, acrylate/epoxy adhesives, acrylate/silicone adhesives, polyurethane adhesives, polyester adhesives, polyamide adhesives and the like.

The inflatable chamber can include a retaining ring assembly. The retaining ring assembly comprises one or more retaining rings bonded about the periphery of 10 an opening (e.g., a vent hole, an inflator hole, etc.) in the inflatable chamber. The retaining ring assembly can comprise one or more retaining rings bonded about the periphery of such an opening on an inner surface of the inflatable chamber, on an outer surface of the inflatable chamber, or on both the inner and outer surfaces. One or more adhesive layers are used to so bond each retaining ring. Each adhesive 15 layer, with or without the corresponding retaining ring, can be an adhesive tape of the type used to bond a structural seam according to the present invention. Thus, the retaining ring and the adhesive layer can form a backed adhesive tape. It is believed that adhesives, other than those used in the present adhesive tape (e.g., lower strength adhesives), can also be used to successfully bond such retaining 20 rings.

The inflatable restraint can also include a tether having each of two opposite ends bonded to one of two opposing inner surfaces of the inflatable chamber. Each end of the tether is bonded to one of the opposing inner surfaces of the inflatable chamber with an adhesive layer so that the adhesive layer is subjected to 25 substantially tensile or pluck loading, not peel loading, during the inflation of the inflatable chamber, as the inflatable restraint is deployed. The adhesive layer is selected so as to withstand the inflation forces resulting from the deployment of the inflatable restraint and so as to maintain the bond between the tether and the opposing inner surfaces. The tether has a length that limits the separation of the 30 opposing inner surfaces during the inflation of the inflatable chamber.

In another aspect of the present invention, the above described adhesive tape is provided for bonding a structural seam of an inflatable restraint, the tape comprising at least one adhesive layer selected such that when used to bond a structural seam of an inflatable restraint, the seam is capable of withstanding inflation forces resulting from deployment of the inflatable restraint.

In an additional aspect of the present invention, a method is provided for making the inflatable restraint described above. The method comprises the steps of: providing at least one sheet of a material suitable for making an inflatable restraint, with the at least one sheet having two edges, and also providing an adhesive tape; 10 forming the at least one sheet so as to define an inflatable chamber having at least one structural seam formed by the two edges; and bonding a substantial portion of the at least one structural seam with the adhesive tape.

When the adhesive tape being provided is a backed adhesive tape, the forming step includes forming the at least one sheet so that the at least one 15 structural seam has a butt joint geometry formed by the two edges, and the bonding step includes applying the backed adhesive tape so as to overlap the edges and bond the structural seam. When the adhesive tape being provided is a adhesive transfer tape, the forming step includes forming the at least one sheet so that the at least one structural seam has a lap shear geometry formed by the two edges overlapping each 20 other so as to form overlapping portions of the at least one sheet, and the bonding step includes disposing the adhesive tape between the overlapping portions so as bond the structural seam.

One of the advantages of the restraints of the present invention is that the 25 seams may be adhesively bonded without the need for expensive adhesive-coated fabrics.

Another advantage of the restraints of the present invention is that adhesively-bonded restraints of the present invention may be manufactured at a lower cost, using less labor than sewn restraints.

Another advantage of the restraints of the present invention is that 30 adhesively-bonded seams avoid stress concentrations in the fabric at the seams and thereby avoid the problem of combing.

Another advantage of the restraints of the present invention is that lighter weight fabrics may be used to construct the inflatable chamber which saves weight and decreases packing volume of the restraint in its un-deployed state. Lighter weight fabrics can also provide a surface that is less abrasive when impacted by a 5 person or object.

#### Brief Description of the Drawings

Fig. 1 is a front view of one embodiment of an inflatable restraint of the present invention.

10 Fig. 2 shows the two sheets used to make the inflatable restraint shown in Fig. 1.

Fig. 3a is a front view of a tube for use in another embodiment of an inflatable restraint of the present invention with an adhesively-bonded seam having a lap-shear geometry.

15 Fig. 3b is a sectional view of the seam of the inflatable restraint of Fig. 3a taken along lines 3b-3b and having an overlap shear geometry according to the present invention.

Fig. 4 is a sectional view of the seam of the inflatable restraint of Fig. 1 taken along lines 4-4 and having an overlap shear geometry according to the present 20 invention.

Fig. 5 is a partial cross-sectional view of a typical sewn seam.

Fig. 6 is a partially sectioned view of an inflatable protective device of the present invention.

25 Fig. 7 is a cross-sectional view of a retaining ring assembly for use on an inflatable restraint in accordance with the present invention.

Fig. 8 is a side view of a deployed inflatable restraint according to the present invention, partially broken away so as to reveal a fully extended tether therein.

Fig. 9 is an enlarged view of the circled area of Fig. 8.

30 Fig. 10 is a front view of another embodiment of an inflatable restraint of the present invention.

Fig. 11 is a front view of an additional embodiment of an inflatable restraint of the present invention.

Fig. 12 is a sectional view of a structural seam having a butt joint geometry according to the present invention.

5 Fig. 13 is a cross-sectional view of a structural seam of an inflatable restraint having a lap shear geometry bonded with a double-sided tape according to the present invention.

### Detailed Description

10 Although the present invention is herein described in terms of specific embodiments, it will be readily apparent to those skilled in this art that various modifications, re-arrangements, re-formulations, and substitutions can be made without departing from the spirit of the invention. The scope of the present invention is thus only limited by the claims appended hereto.

15 The inflatable restraints of the present invention include an inflatable chamber made from at least one sheet of material (e.g., a fabric), suitable for use in the inflatable restraint, forming at least one structural seam, and have a substantial portion of at least one structural seam bonded with an adhesive or an adhesive tape. "Inflatable restraint" as used herein refers to any inflatable restraint device, including 20 driver-side airbags, passenger airbags, side impact airbags, inflatable seat belt restraints, knee bolsters, head liner curtains, and the like. "Structural seam" as used herein refers to a seam in the inflatable restraint that is subjected to gas pressure or forces due to inflation of the inflatable chamber and which must maintain integrity to a predetermined pressure during the operation of the inflatable restraint for its 25 intended purpose. Examples of non-structural seam applications of the present adhesive or adhesive tape include attaching fabric or material to the inflatable chamber to reinforce a vent hole or an inflator hole and the like.

30 Generally, the inflatable chamber may be any shape and configuration that allows the use of an adhesive to bond together the inflatable chamber. It is desirable for the inflatable chamber to be of a shape which allows for the structural seams to have a lap-shear geometry or butt joint geometry. Having a "lap-shear

"geometry" means that the seams are overlapping and positioned so that during inflation of the inflatable chamber, the force applied to the seams is substantially lateral or shear force, rather than substantially a "peel" force. Having a "butt joint" geometry means that the edges of the material brought together to form the seam

5 are not overlapping but substantially abutted (i.e., adjacent to one another) or joined edge-to-edge. In such a geometry, the bonded seam will also be subject substantially to shear forces, rather than substantially "peel" forces, when the inflatable restraint is deployed. A seam having lap-shear geometry is shown in Figs. 3a, 3b and 4 (described in detail below). A seam having a butt join geometry

10 is shown in Fig. 12. This is in contrast to typically sewn seams of known inflatable restraints which are configured such that "peel" or perpendicular force acts upon the seam during inflation of the restraint. A peel type seam is shown in Fig. 5 (described in detail below). Useful shapes include polygons, for example, octagons, squares, triangles, and the like; pyramids; circles; interlocking "baseball" shaped

15 pieces and interlocking "dogbone" shaped pieces. Other useful shapes that can be adhesively bonded using lap-shear geometry seams includes those described in U.S. Patent Nos. 4,988,118; 5,454,594; and 5,482,317, all of which are incorporated in their entirety herein by reference.

The inflatable restraints of the present invention may be made of a single

20 piece or sheet of material or of two or more sheets of material. An inflatable restraint of the present invention may generally be made from a single sheet of material by folding the material and forming edges and then bonding the respective edges with an adhesive in a lap-shear or butt joint geometry. An inflatable restraint of the present invention may also be made by adhesively bonding two or more

25 sheets of material together at their respective edges. The inflatable restraints of the present invention may also have additional adhesively-bonded seams which give the uninflated restraint a three-dimensional structure. For example, an inflatable restraint, adhesively bonded together according to the present invention, may be folded inwardly at a seam and then the folds are adhesively bonded together to form

30 a seam which extends into the vertical plane of the inflatable chamber.

Generally, any fabric or material suitable for use in an inflatable restraint may be used to make the inflatable restraints of the present invention. Useful materials include sheets made from fabrics of nylon 6, nylon 6,6, Kevlar®, and polyester (DACRON®) yarns. It is desirable for the fabrics to be woven from such 5 yarns having a denier of about 840 or less. It is more desirable for the fabric bonded according to the present invention to have a denier of about 630 or less. It is even more desirable for the fabric to have a denier of about 420 or less. By using adhesive bonding according to the present invention, it is believed that the inflatable chamber can even be made from relatively lightweight fabrics (i.e., about 210 denier 10 or less), compared to that typically used in the past. The useful fabrics may also have a balanced or unbalanced weave, that is, the fabric may be woven with fabrics having the same or a different denier and thread counts in the warp and filling directions.

The sheet materials of the present inflatable restraints may be coated or 15 uncoated. Coatings are used to make the fabric less permeable to the inflation gas. Satisfactory results have been obtained with uncoated and silicone coated nylon fabrics. Other useful coatings may also include for example, rubber, polyurethane, and neoprene. Commercially available fabrics include silicone coated nylon 6,6 Fabric Style Nos. 64318 and 64362, available from Precision Fabrics Group Inc., 20 Greensboro, North Carolina; uncoated nylon 6,6 (630 denier), available from Highland Industries Inc., Greensboro, NC; and silicone coated or uncoated nylon woven fabric (420 denier) from Milliken & Co., Spartanburg, South Carolina.

The adhesive tape used to bond structural seams in the inflatable restraints of the present invention may be any adhesive tape that is compatible with the 25 materials used in the inflatable restraint and capable of withstanding the inflation forces caused by deployment of the inflatable restraint. In other words, the adhesive tape should exhibit sufficient shear-holding power such that the structural integrity of the seam and the restraint as a whole is maintained during the unused life of the inflatable restraint, as well as during deployment. Generally, the strength 30 of the tape-bonded structural seams of the present invention is dependent on the type of fabric used for the inflatable chamber; the backing, if present, and the

adhesive used in the adhesive tape; and the design of the inflatable restraint. It is desirable for an inflatable restraint of the present invention to have tape-bonded structural seams that withstand an internal inflation pressure of from at least about 2 psi (14 kPa) to about 60 psi (414 kPa), or more depending on the requirements of 5 the particular inflatable restraint. It is believed desirable for a tape-bonded structural seam, according to the present invention, to have a shear strength of at least about 50 psi (345 kPa) and, more desirably, at least about 75 psi (517 kPa). It is desirable for a tape-bonded structural seam, according to the present invention, to have a shear strength of at least about 100 psi (690 kPa) and, more desirably, at 10 least about 120 psi (827 kPa).

Any coated or uncoated (e.g., with silicone) material that meets deployment and durability requirements required for inflatable restraints may be useful as a backing in the present adhesive tape. Such materials may include, but are not limited to, suitable woven nylon fabrics, woven polyester fabrics, Kevlar®, 15 Spectra®, films, nonwovens, including nonwoven fabrics, laminates of films, yarns and/or fibers, and the like. It is desirable for the backing to be made of materials like those used to make the sheet(s) for the inflatable chamber. It has been found desirable for the backing to be an uncoated woven nylon fabric. Though, the fabric backing can have a coating (e.g., silicone) on one or both sides, with the adhesive 20 coated onto a coated side or an uncoated side.

The adhesive used to bond structural seams in the inflatable restraints of the present invention may be any adhesive that is compatible with the materials used in the inflatable restraint and capable of withstanding the inflation forces caused by deployment of the inflatable restraint. In other words, the adhesive should exhibit 25 sufficient shear-holding power such that the structural integrity of the seam and the restraint as a whole is maintained during the unused life of the inflatable restraint, as well as during deployment. The type and amount of adhesive used is largely dependent on the type of fabric and/or coating used to make the inflatable restraint. For example, it is desirable to use a silicone adhesive for bonding a silicone coated 30 fabric of nylon 6,6. A silicone adhesive can also be used to bond an uncoated fabric of nylon 6,6.

Suitable adhesives provide a high level of bonding to low energy surfaces and are flexible through a temperature range of from about -30°C to 90°C. Such adhesives also do not adversely affect the fabric or fabric coating, are stable for at least 10 years, and do not outgas or "fog" excessively. Silicone adhesives can 5 provide long-term durability and are useful over a wide range of temperature, humidity and environmental conditions, and can be used effectively to bond to surfaces coated with silicone or other high and low surface energy coatings, such as coatings found on the sheet materials currently used to make inflatable restraints.

For the adhesive tapes, any adhesive that imparts the desired shear holding 10 power to the tape and that possesses properties that allow it to be applied to a backing, if applicable, so as to produce a usable adhesive tape for inflatable restraint applications may be employed in the present adhesive tape. It is desirable for the adhesive used in the present adhesive tape to be a hot-melt or pressure-sensitive adhesive (PSA). It is also desirable for the class of adhesives used in the present 15 adhesive tape to be silicone adhesives. Silicone adhesives can provide long-term durability and are useful over a wide range of temperature, humidity and environmental conditions, and can be used effectively to bond to surfaces coated with silicone or other high and low surface energy coatings, such as coatings found on the sheet materials currently used to make inflatable restraints.

20 A desirable silicone adhesive that has been used to bond together inflatable restraints, with satisfactory results, is a silicone pressure-sensitive adhesive, commercially available under the tradename SILGRIP® PSA529 from GE Silicones, Waterford, NY. This adhesive was fully cured or cross-linked after the adhesive was applied and the seam(s) of the inflatable restraint formed. The cross- 25 linking agent successfully used with the GE PSA 529 adhesive was the aminosilane catalyst/cross-linking agent, commercially available from OSi Specialties, Inc. of Endicott, New York, under the product designation OSi A-1100 (aminopropyltriethoxysilane). This catalyst/cross-linking agent is also commercially available from GE Silicones, Waterford, NY under the product designation SRC18.

30 General Electric provides its PSA529 as a 55 wt% solids solution of silanol terminated linear polydimethylsiloxane gum and a silanol functional MQ resin

(consists of M  $[(CH_3)_3SiO_{1/2}]$  and Q  $[SiO_{4/2}]$  structural units) that has been slightly condensed to increase the cohesive strength of the adhesive. The resin to gum ratio in the GE PSA529 is believed to be about 62/38 (MQ resin/gum) by weight. The GE PSA529 can be cured by either peroxide-cure (free radical) or condensation-cure. The recommended condensation cure formulation is 100 parts by weight (pt) of the PSA529 with 3.3 pt of the GE catalyst SRC18 (aminopropyltriethoxysilane). Satisfactory results have been obtained employing 3 pt of SRC18 per 100 pt PSA529.

Because the SRC18 catalyst is an active form of condensation catalyst, a 10 catalyzed solution of the PSA529 will continue to advance in cure, as evidenced by increased viscosity, until gelled. Advancement of cure may be retarded significantly by diluting the adhesive to a lower concentration with solvent. A catalyzed GE PSA529 adhesive sample, at 30% solids, may have a useful bathlife in a closed container of up to 3 months.

15 It is believed that a wide variety of silicone adhesive compositions are useful in constructing an inflatable restraint of the present invention. Such compositions cover a wide range of moduli, including those compositions of quite low modulus that exhibit pressure-sensitive tack, compositions of intermediate modulus that exhibit pressure-sensitive tack at elevated temperature, and the high modulus 20 silicone rubber adhesives that possess no pressure-sensitive tack. Examples of other adhesives that may be useful in adhesively bonding inflatable restraints are discussed below.

Silicone pressure-sensitive adhesives (PSAs), like those disclosed herein, generally comprise a high molecular weight linear and/or branched 25 polydiorganosiloxane polymer that contains SiOH functionality and an SiOH functional copolymeric silicone resin (also referred to as a silicate resin) comprising triorganosiloxy units and  $SiO_{4/2}$  units. Examples of silicate resins include MQ resins, MQD resins, and MQT resins. The SiOH groups on the copolymeric resin and the polydiorganosiloxane polymer can be reacted together via condensation 30 reaction, as taught in U.S. Patents Nos. 2,738,721; 2,814,601; 2,857,356; 3,528,940; 4,309,520; 5,281,455; and great Britain Patent No. 998,232, which are

incorporated in their entirety herein by reference, to provide a solvent soluble silicone PSA having improved cohesive strength. Such a composition may be employed without further cure. It is desirable for these compositions to be subsequently cured to further increase cohesive strength.

5 In the uncured state the tack level of silicone PSAs is primarily controlled by the amount of silicate resin (e.g., MQ resin) employed. Adhesives ranging from those exhibiting high tack to those possessing no tack at room temperature can be obtained by appropriately selecting the silicate resin concentration. Generally, increases in silicate resin concentration decrease the tack of the adhesive. At MQ 10 resin concentrations of greater than about 75-80 wt%, the adhesive can become too glassy and fragile for use in bonding an inflatable restraint. A high tack and a low tack silicone PSA can be blended to obtain properties that are intermediate of the two adhesives. U.S. Patent No. 5,096,981, which is incorporated in its entirety herein by reference, describes the blending of such adhesives. In the cured state the 15 tack of silicone PSAs is primarily controlled by the cross-link density of the composition, with increased cross-link density resulting in decreased tack and peel, and increased cohesive strength.

In general, silicone PSAs of this type may be cured by condensation-cure, peroxide cure, or a combination of the two. Condensation cure may be effected by 20 use of several different types of catalysts. Commonly employed catalysts for such a reaction include amines, aminosilane derivatives, titanates, and carboxylic salts of lead, tin, and zinc. Also believed useful are the UV triggered condensation catalysts described in U.S. Patent Application Serial No. 08/815,029, filed March 14, 1997, entitled CURE-ON-DEMAND MOISTURE-CURABLE COMPOSITIONS 25 HAVING REACTIVE SILANE FUNCTIONALITY, assigned to the assignee of the present application, and incorporated in its entirety herein by reference. A condensation catalyst may be employed alone or in combination with a cross-linking agent. Common cross-linking agents suitable for use include multifunctional silanes or siloxanes having moisture curable groups, e.g., alkoxy, alkenoxy, alkamido, 30 acylamido, or dialkylketoximino. Some molecules can serve as both catalyst and

cross-linking agent as is the case with aminopropyltriethoxysilane and N-(2-aminoethyl)-3-aminopropyltrimethoxysilane.

With a peroxide cure, a diaryl peroxide cross-linking compound is typically added to the adhesive solution. The adhesive is then applied to a backing and 5 heated moderately to remove solvent. This step is followed by further heating to elevated temperatures to activate the cross-linking agent as disclosed in U.S. Patent No. 4,039,707, which is incorporated in its entirety herein by reference. At elevated temperatures the peroxide compound decomposes to form free radicals that abstract protons from organic substituents along the polydiorganosiloxane backbone. These 10 resultant radicals then combine to form rigid cross-links between the polydiorganosiloxane chains. These adhesive compositions can also be cured using two component room temperature free radical curatives consisting of a cross-linking catalyst and an accelerator. Common cross-linking catalysts useful in this two component curative can include peroxides and hydroperoxides such as 15 dibenzoyl peroxide, t-butyl hydroperoxide, and cumene hydroperoxide, which are not active at room temperature. The accelerator component of the curative includes the condensation reaction product of a primary or secondary amine and an aldehyde. Common accelerators of this type are butyraldehyde-aniline and butyraldehyde-butyramine condensation products such as, for example, that sold by 20 E.I. duPont de Nemours & Co. as Accelerator 808<sup>TM</sup> and Accelerator 833<sup>TM</sup>. This catalyst system may be employed to prepare a two-part free radically curable adhesive system where the adhesive system is divided into two parts and the cross-linking catalyst is added to one part and the accelerator is added to the other part. Upon mixing, this two component system typically cures at room temperature. 25 Alternatively, the cross-linking catalyst can be incorporated in the adhesive and the accelerator can be applied to a substrate such that when the free radically curable adhesive, containing the cross-linking catalyst, contacts the "primed" substrate surface, cure proceeds immediately at room temperature.

Silicone PSAs prepared by addition-cure chemistry generally comprise 30 polydiorganosiloxanes having alkenyl groups, MQ resin having silicone-bonded hydrogen, silicone bonded alkenyl, or silanol groups, Pt or other noble metal

hydrosilation catalyst to effect the curing of the silicone PSA, and optionally a cross-linking or chain extending agent and hydrosilation inhibitor to extend bath life. Examples of such compositions are found in U.S. Patents Nos. 3,527,842; 3,983,298; 4,774,297; European Patent Publication Nos. 355,991; and 393,426, 5 and Japanese Kokai HEI 2-58587, which are incorporated in their entirety herein by reference. Advantages of the use of addition-cure silicone PSAs include reduced solution viscosity as compared to silicone PSAs prepared via condensation chemistry, higher solids content, stable viscosity with respect to time, and lower temperature cure. While silicone PSAs prepared by condensation chemistry are 10 typically delivered from solvent, addition-cure silicone PSAs can be prepared in a solventless format as shown in U.S. Patents Nos. 5,169,727 and 5,248,739, which are incorporated in their entirety herein by reference. Curing is typically effected by thermally activating the hydrosilation catalyst, however hydrosilation catalysts activated by actinic radiation may also be useful in these compositions as described 15 in U.S. Patents Nos. 4,530,879 and 4,510,094, which are incorporated in their entirety herein by reference.

Another class of silicone PSAs which may be useful in the present invention are those cured by free radical polymerization of unsaturated groups. Such compositions generally comprise a polydiorganosiloxane polymer bearing 20 ethylenically unsaturated groups, sufficient silicate resin (e.g., MQ resin) to tackify the composition for the intended purpose, and optionally free radically polymerizable vinyl monomer and free radical initiator. Such compositions are described in U.S. Patents Nos. 5,514,730; 5,264,278; and 5,091,483, which are incorporated in their entirety herein by reference.

25 Tackified polydiorganosiloxane polyurea segmented copolymers represent another adhesive type having utility in the instant invention. In general, these compositions each comprise a polydiorganosiloxane polyurea segmented copolymer and a silicate (e.g., MQ) tackifying resin and provide adhesives ranging in modulus from PSAs, to heat activated PSAs, to non tacky high strength heat activated or hot 30 melt adhesives. Examples of such compositions are described in the U.S. Patent No. 5,461,134, which is incorporated in its entirety herein by reference. Examples

of such compositions are also described in the PCT Patent Application No. PCT/US96/05852 (Publication No. WO96/35458) entitled TACKIFIED POLYDIORGANOSILOXANE POLYUREA SEGMENTED COPOLYMERS AND A PROCESS FOR MAKING SAME, which was filed April 25, 1996, is 5 assigned to the assignee of this application, and the disclosure of which is incorporated in its entirety herein by reference. Copolymers that can be used to make such silicone adhesives are disclosed in the PCT Patent Application No. PCT/US96/05869 (Publication No. WO96/34029) entitled POLYDIORGANOSILOXANE POLYUREA SEGMENTED COPOLYMERS 10 AND A PROCESS FOR MAKING SAME, which was filed April 25, 1996, is assigned to the assignee of this application, and the disclosures of which is incorporated in their entirety herein by reference. Such compositions require no cure and may be delivered to the area to be bonded in a number of ways including from solvent, from an extrusion die at elevated temperature, or in tape form. If the 15 tape product is a PSA it may be applied to the bond area as received. Alternatively, if the tape product is a higher modulus tack free composition (heat activated or hot-melt adhesive), the tape may be applied to the bond area and activated with heat and pressure to create the bond.

Another class of silicone PSAs useful in constructing articles of the present 20 invention are those compositions comprising a curable polydiorganosiloxane oligourethane segmented copolymer tackified with MQ resin. Such compositions can be formulated to be cured under free radical or moisture cure conditions and provide adhesives ranging in modulus from PSAs, to heat activated PSAs, to non tacky high strength adhesives. Examples of such compositions are described in the PCT Patent 25 Application No. PCT/US96/05829 (WO96/34028) entitled TACKIFIED POLYDIORGANOSILOXANE OLIGOUREA SEGMENTED COPOLYMERS AND A PROCESS FOR MAKING SAME, which was filed April 25, 1996, is assigned to the assignee of this application, and the disclosure of which is incorporated in its entirety herein by reference. Copolymers that can be used to 30 make such silicone adhesives are disclosed in the PCT Patent Application No. PCT/US96/05870 (WO96/34030) entitled POLYDIORGANOSILOXANE

## OLIGOUREA SEGMENTED COPOLYMERS AND A PROCESS FOR

MAKING SAME, which was filed April 25, 1996, is assigned to the assignee of this application, and the disclosure of which is incorporated in its entirety herein by reference.

5 Depending on the adhesive composition employed, the adhesive may be delivered in a number of ways including from solvent, as a tape product, or in neat form at elevated temperature such as from an extrusion die. If the composition is free radically cured it may then be exposed to conditions appropriate to achieve cure, e.g., actinic radiation, thermal treatment, etc. depending on the initiation system, if any, employed.

10 Moisture curable room temperature vulcanizable (RTV) silicones are yet another useful class of adhesive-type material which may be used in accordance with the present invention. Upon exposure to atmospheric moisture, RTV silicones undergo hydrolysis and condensation reactions to yield high strength silicone adhesives, sealants, and elastomers. Two basic cure chemistries are employed to

15 prepare RTV silicones adhesives, acetoxy-based cure systems and alkoxy-based cure systems. Acetoxy-based adhesives are described in U.S. Pat. Nos. 3,133,891 and 3,035016; methoxy-based adhesives are described in U.S. Pat. No. 3,127,363, the disclosures of all of these patents are incorporated in their entirety herein by reference. Typical of the acetoxy-cure system would be an adhesive comprising an

20 SiOH terminated polydiorganosiloxane polymer, a multifunctional acetoxy silane cross-linker, such as methyltriacetoxy silane, and optionally a condensation catalyst, often of the tin (IV) type. Upon exposure to atmospheric moisture the cross-linker hydrolyzes, liberating acetic acid, reacts with the silanol functional polymer, and as condensation proceeds results in formation of the cross-linked adhesive network.

25 The alkoxy-based systems are very similar to the acetoxy-based systems, one principle difference being that alkoxy rather than acetoxy functional cross-linkers are employed, such as methyltrimethoxysilane. Methoxy-based cross-linkers and silanol functional polymers do not spontaneously react with atmospheric moisture under pH-neutral conditions, and therefore, a catalyst is required to facilitate cure.

30 Adhesives are typically filled to both control viscosity of the uncured composition and reinforce the cured adhesive. Silicone RTV adhesives commonly employ

adhesion promoters such as trialkoxy- or dialkoxy-substituted silanes, e.g., aminopropyltrimethoxysilane, cyanoethyltriethoxysilane, and glycidoxypropyltrimethoxysilane, to enhance adhesion to difficult to bond substrates.

5       Silicone adhesives prepared by addition-cure chemistry generally comprise polydiorganosiloxanes having alkenyl groups, a silicon-hydride functional cross-linking agent, Pt or other noble metal hydrosilation catalyst to effect curing of the adhesive, and optionally a silicon-hydride chain extending agent; a silicate (e.g., MQ) resin having silicon-bonded hydrogen, silicon-bonded alkenyl, or silanol groups; hydrosilation inhibitor; filler; and/or adhesion promoter. Such products may be delivered as one-part compositions or two-part compositions, and may be provided in the form of pourable fluid, thick paste, or semi-solid. Adhesion promoters, e.g., epoxy- and alkenyl-substituted silanes, such as vinyltriethoxysilane, vinyltriacetoxysilane, and glycidoxypropyltrimethoxysilane, as well as siloxane 10 oligomers bearing both unsaturation and silanol functionality on the same molecule, are used in such compositions to enhance adhesion to difficult to bond substrates. Cure is typically obtained by exposing the adhesive to temperatures in the range of 80°C to 150°C for an appropriate length of time, although room temperature cure addition-cure adhesives are known. An example of a two-part thermally activated 15 addition-cure adhesive is found in US Patent No. 4,087,585, which is incorporated in its entirety herein by reference.

20       Other suitable silicone adhesives may also include block copolymer adhesives, acrylate adhesives, acrylate/epoxy adhesives, acrylate/silicone adhesives (such as, for example, that disclosed in U.S. Patent No. 5,308,887 which is incorporated in its entirety herein by reference), polyurethane adhesives, polyester adhesives, polyamide adhesives and the like.

25       Generally, the strength of the adhesively-bonded structural seams of the present invention is dependent on the fabric type, the adhesive, the seam geometry and the design of the inflatable restraint. It is desirable for an inflatable restraint of 30 the present invention to have adhesively-bonded structural seams that withstand an internal inflation pressure of from at least about 2 psi (13.8 kPa) to about 60 psi

(413.7 kPa) ), or more depending on the requirements of the particular inflatable restraint. It is believed desirable for an adhesive bonded structural seam, according to the present invention, to have a shear strength of at least about 50 psi (345 kPa) and, more desirably, at least about 75 psi (517 kPa). It is desirable for an adhesive 5 bonded structural seam, according to the present invention, to have a shear strength of at least about 100 psi (690 kPa) and, more desirably, at least about 120 psi (827 kPa).

Generally, the adhesive is applied to at least partially coat the fabric, forming one or both sides of the seam, to a thickness that will result in a sufficiently strong 10 bond. It is desirable for the thickness of the applied adhesive to be in the range of from about 0.5 to about 15 mils (0.005 to 0.038 cm) and more desirable from about 0.5 to about 10 mils (0.005 to 0.025 cm). The amount of overlap of the adhesively-bonded seams having lap-shear geometry is that amount which is sufficient to withstand the inflatable restraint inflation pressures without failing. The amount of 15 overlap in an adhesive bonded lap-shear geometry seam of the present invention can be in the range of from about 1/8 inch (0.38 cm) to the width of the inflatable chamber. The width of the overlap may also vary along the length of the seam. The amount of overlap should not be so excessive as to limit or prohibit sufficient flexibility of the inflatable restraint. It is desirable for the lap-shear seams of the 20 present invention to overlap in the range of about 1/8 inch (0.38 cm) to about 2 inches (5.08 cm). Satisfactory results have been obtained with overlaps in the range of from about 0.5 inch (1.27 cm) to about 1 inch (2.54 cm). It can be desirable, if coated fabrics are used, for a coated fabric surface to be adhesive bonded to an uncoated fabric surface.

25 The adhesive bonded inflatable restraints of the present invention are made by cutting the fabric sheet or sheets into the desired shapes, applying adhesive to each piece of fabric in the areas to be bonded, and then forming a lap-shear seam by folding or overlapping edge portions of one piece of fabric onto the other.

An example of an adhesive bonded inflatable restraint of the present 30 invention is shown in Fig. 1. The inflatable restraint 10 comprises two adhesively-bonded sheets 14, 16 (see Fig. 2) made from, for example, a nylon 6,6 fabric which

when adhesively bonded together at respective edges (see Fig. 4), forms an inflatable chamber 12. As shown more particularly in Fig. 2, sheets 14, 16 have a generally octagonal shape, with sheet 14 having a smaller diameter. The sheets 14, 16 are bonded with an adhesive 17 to form inflatable chamber 12 by means of 5 seams 20 having lap-shear geometry as shown more particularly in Fig. 4. The seams 20 are made from folded edge sections or flaps 22 of sheet 16 which are folded onto and overlap the edge 24 of sheet 14. Sheet 16 has a plurality of cuts or slices 26 which define flaps 22. Sheet 16 also has a centrally located inflator hole 11 with corresponding mounting holes 13. Chamber 12 may also have vent 10 holes 15.

Fig. 3a illustrates an adhesively bonded tube 28 which forms part of an inflatable seat belt type inflatable restraint 30. The tube 28 is formed by a rectangular sheet 32, of a suitable material, which has two opposite edges 31 and 33 joined to form a structural seam 34 along the length of the tube 28. The structural 15 seam 34 is bonded with one or more layers of an adhesive 36 according to the present invention so as to form the lap shear joint configuration shown in Fig. 3b.

Referring to Fig. 6, the present invention includes an inflatable protective device 30 which comprises an adhesive bonded inflatable restraint 10 of any desired configuration within a housing 40 which is attached to an inflation device 50. The 20 inflation device 50 may be chosen from any of the inflation devices known to those skilled in the art. Specific examples of useful inflation devices and housings are described in U.S. Patent No. 4,828,286, incorporated by reference herein. Other inflation devices and housings that are compatible with the inflatable restraints of the present invention may be selected by those skilled in the art without undue 25 experimentation.

Referring to Fig. 7, a retaining ring assembly 52, in accordance with the present invention, can comprise one or more retaining rings 54 bonded about the periphery of an opening 56 (e.g., a vent hole, an inflator hole, etc.) in an inflatable chamber defined by at least one sheet 60 of a fabric or other material suitable for an 30 inflatable restraint. The retaining ring assembly 52 can comprise one or more retaining rings 54 bonded about the periphery of such an opening 56 on an inner

surface 62 of the inflatable chamber 58, on an outer surface 64 of the inflatable chamber 58, or on both the inner and outer surfaces 62 and 64, as shown. One or more of an adhesive layer 66 is used to so bond each retaining ring 54. Each adhesive layer 66, without the corresponding retaining ring 54, can be in the form of

5 an adhesive transfer tape. Alternatively, each retaining ring 54 and the corresponding adhesive layer(s) 66 can form a backed adhesive tape ring 68.

Referring to Figs. 8 and 9, an inflatable restraint 82 can include a tether 84 having a cord or ribbon 85 with each of two opposite ends 86 and 88 bonded to one of two opposing inner surfaces 90 and 92, respectively, of the inflatable chamber 94 of the restraint 82. Each end 86 and 88 of the tether 84 is bonded to its corresponding inner surface 90 and 92 of the inflatable chamber 94 with an adhesive layer 96 so that the adhesive layer 96 is subjected to substantially tensile loading, not peel loading, during the inflation of the inflatable chamber 94, as the inflatable restraint 82 is deployed. At least substantial, if not pure, tensile loading forces can

10 be obtained by securing or otherwise forming a patch 98 of suitable material (e.g., like that used to make the tether cord or ribbon 85, the inflatable chamber 94, etc.) on each end 86 and 88. Each patch 98 can be an integral part of the cord or ribbon 85 or secured to the ends 86 and 88 such as, for example, by sewing, stapling, adhesive bonding or a combination thereof. To obtain such tensile loading

15 on the bond made by adhesive layers 96, each end 86 and 88 should be centrally positioned on its corresponding patch 98. In addition, each patch 98 should be of sufficient surface area to provide the adhesive bonding strength required. The adhesive layer 96 is selected so as to withstand the inflation forces resulting from the deployment of the inflatable restraint 82 and so as to maintain the bond between

20 the tether 84 and the opposing inner surfaces 90 and 92. The adhesive layer 96 can be an adhesive transfer tape according to the present invention. The tether 84 has a length that limits the separation of the opposing inner surfaces 90 and 92 during the inflation of the inflatable chamber 94, as desired.

25

It is believed that adhesives, other than that used to bond structural seams,

30 can also be used to successfully bond such retaining rings 54, depending on the structural reinforcement requirements of the retaining ring assembly 52. In

addition, each retaining ring 54 can be made of the same material as the sheet 60, or tailored to meet the structural requirements of the desired reinforcement. For example, a retaining ring of fabric coated with silicone or a ceramic based material may be required to function as a heat shield.

5        The adhesive tape may be made using known methods of making backed adhesive tape or adhesive transfer tape. The adhesive tape can be slit into rolls, cut into strips, or cut into shapes. When backed, the adhesive tape can be cut along the fabric warp or weft direction, or at any angle across the fabric. To make an inflatable restraint in accordance with the present invention, one or more sheets of a  
10 material suitable for use in an inflatable restraint are provided. The material is manipulated to form an inflatable chamber having at least one structural seam. The structural seam is formed by substantially abutting edges of the material to form a butt joint seam, or by overlapping the edges to form a lap shear seam. The tape as described herein is then applied to bond the seam by pressure or heat or both,  
15 depending on the adhesive used.

Referring to Fig. 10, a circular airbag type inflatable restraint 100 includes two circular sheets 112 and 114, made of a suitable fabric or other material, and a structural seam 116 at the perimeter thereof. The sheets 112 and 114 define the inflatable chamber portion of the restraint 100. The seam 116 is formed  
20 circumferentially around the entire periphery of the airbag 100 and has a butt joint geometry like that shown in Fig. 12 and is bonded using a backed adhesive tape 118, according to the present invention. The airbag 100 includes an inflator hole 120 and a vent hole 122. The inflator hole 120 is reinforced with a retaining ring assembly 124, like that shown in Fig. 7. The retaining ring assembly 124 is  
25 adapted, in a conventional manner, to receive a suitable inflator. The vent hole 122 is reinforced with another retaining ring assembly 126 which is the same or similar to the assembly 124.

Referring to Fig. 11, a square airbag type inflatable restraint 38 is constructed from one square sheet 40 of suitable material folded onto itself, at each  
30 corner, to create structural seams 42 on the diagonals. Each of the diagonal seams 42 has a butt joint geometry like that shown in Fig. 12 and is bonded using a

length of backed adhesive tape 44, according to the present invention. An inflator hole 46 is formed by cutting (e.g., by die cutting) an appropriate portion of each folded corner of the sheet 40. Like the above described circular airbag 100, the square airbag 38 includes a retaining ring assembly 48 for the inflator hole 46 and a 5 retaining ring assembly 50 for a vent hole. The retaining ring assembly 48 can be applied so as to provide all of the reinforcement for each portion of the corners defining the inflator hole 46. That is, each tape 44 can be cut short so as not to cover the full length the corresponding seam 42 and to stop just short of reaching the assembly 48. Alternatively, each length of the tape 44 can be cut so as to bond 10 the entire length of each seam 42. With this configuration, the retaining ring 48 can be positioned so as to overlap the corresponding end of each tape 44 and bond to each tape 44 and each folded corner of the sheet 40.

Fig. 12 illustrates an adhesively bonded structural seam 134 that is bonded using a backed adhesive tape 136 so as to form a butt joint configuration. The 15 adhesive tape 136 includes a backing 135 and an adhesive layer 137 of suitable materials, according to the principles of the present invention. Alternatively, the edges 131 and 133 could be overlapped (i.e., one edge 131 or 133 is underneath the other) and the resulting overlapping seam bonded with the tape 136 such that the underlying edge 131 or 133 is not in contact with the tape 136.

20 Whether in the form of an adhesive transfer tape or a backed adhesive tape, it can be desirable for the adhesive layer to be mounted on a suitable release liner. Whether a release liner is used depends, at least in part, on the degree to which the adhesive bonds to itself (in the case of the adhesive transfer tape) or the degree to which the adhesive bonds to the exposed surface of the adhesive backing (in the 25 case of the backed adhesive tape). It can also be desirable to use a release liner when the layer of adhesive forming the transfer tape is not self-supportive.

Each backed adhesive tape ring 68 and each adhesive transfer tape layer 66, as well as individual retaining rings 54, can be formed, for example, by being die cut to the shape desired. The use of a release liner can facilitate a die cutting-type 30 forming operation. If the adhesive used is a hot melt-type and/or a pressure sensitive-type, the adhesive tape can be bonded to the desired substrate (i.e., either

a sheet or a retaining ring) with heat and/or pressure in a conventional manner.

Both heat and pressure can be applied when the adhesive exhibits both heat and pressure activated characteristics.

Referring to Fig. 13, a structural seam 70 in an inflatable restraint (e.g., like 5 that shown in Fig. 3a) can be bonded in a lap shear geometry using an adhesive transfer tape 72, in accordance with the present invention. The seam 70 is formed by overlapping portions 74 and 76 of one or more sheets of a suitable material for an inflatable restraint. The tape 72 can be a double sided adhesive tape, as shown, with one or more of an adhesive layer 78 on both sides of a reinforcement layer or 10 backing 80. Each layer 78 is bonded to one of the overlapping portions 74 and 76. The backing 80 can be any suitable material which will not delaminate from the adhesive layers 78 and provides the required structural support for the adhesive layers 78. The adhesive transfer tape can, alternatively, comprise one or more adhesive layers without a backing. It is desirable for such an adhesive tape to be 15 self-supportive, without a support backing, when used to bond a structural seam of the inflatable restraint.

## Experimental

### Test Procedures

#### Lap-Shear Test

Two 4 inch (10.2 cm) by 5 inch (12.7 cm) samples of the fabric to be tested 20 were cut. The two fabric samples were adhesively bonded together with a 1 inch (2.54 cm) overlap. The adhesive was applied to the area(s) to be bonded in an amount to visually cover the area to be bonded. The bonded fabric samples were 25 allowed to cure, and then were cut into three 1 inch (2.54 cm) by 5 inch (12.7 cm) strips. The bonded strips were tested for shear strength in a tensile testing machine (Instron™ Model No. 1122), with an initial jaw gap of 4 inches (10.2 cm), a jaw width of 1 inch (2.54 cm), a crosshead speed of 12 inch/min (30 cm/min), and a scale range of 200 lbf (889.6 N). The test was performed three times for each 30 adhesive/fabric combination and the results were averaged.

**Peel Test (180° T-Peel)**

Two 4 inch (10.2 cm) by 5 inch (12.7 cm) samples of the fabric to be tested were cut. The two fabric samples were adhesively bonded together with a 4 inch (10.2 cm) overlap, with the edges parallel. The adhesive was applied to the area(s) 5 to be bonded in an amount to visually cover the area to be bonded. After bonded fabric samples were allowed to cure, the samples were cut into three 1 inch (2.54 cm) by 5 inch (12.7 cm) strips. The bonded strips were tested for 180° peel strength in a tensile testing machine (Instron™ Model No. 1122) with an initial jaw gap of 1 inch (2.54 cm), a jaw width of 1 inch (2.54 cm), a crosshead speed of 12 10 inch/min (30 cm/min), and a full scale range of 20 lbf (89.0 N). The test was performed three times for each adhesive/fabric combination and the results were averaged.

**Fabric Material**

15 PFG64318 - A 210 X 45 denier fabric of silicone coated nylon 6,6 Style No. 64318, available from Precision Fabrics Group, Greensboro, NC.

**Adhesives**

GE PSA529 - SILGRIP® PSA529 silicone pressure-sensitive adhesive 20 available from GE Adhesives, Waterford, NY, mixed with 3.3 parts per hundred OSi A-1100 aminosilane crosslinking agent, commercially available from OSi Specialties, Inc., Endicott, NY.

Primer 1.0 - A 50/50 weight percent blend of OSi A-1100 and Y-11597, both available from Osi Specialties, Inc., Endicott, NY.

25

**Failure Mode**

FT - Fabric Tore

SF - Seam Failure

NF - No Failure

30

**Examples A & B**

Samples of silicone coated and uncoated nylon 6,6 fabrics were tested for adhesive-bond strength using the lap-shear and peel test methods described above. The GE PSA529/ OSi A-1100 adhesive mixture (i.e., the catalyzed GE PSA529) 5 was applied to both sample strips of each sample. The samples bonded with the catalyzed GE PSA529 adhesive were allowed to cure for 7 days at room temperature, prior to testing. Coated fabrics were tested by bonding a coated side to an uncoated side, unless otherwise noted. The reported adhesion values are the average of three measurements. The results are shown in Table 1 below.

10

**TABLE 1**

Ex.	Fabric Type	Adhesive Type	Primer	Adhesion(N)		Failure Mode
				Peel	Shear	
A	PFG 64318	GE PSA529	None	23.1	411.5	FT
B	PFG 64318	GE PSA529	1.0	6.7	296.3	SF

**Airbag Examples C-F**

15 Octagon shaped airbags were fabricated by cutting two panels of PFG Type 64318 silicone coated nylon fabric. The first piece of fabric had a diameter of approximately 365 mm and each side had a length of about 140 mm. The second piece of fabric had a diameter of approximately 391 mm with a side length of about 152 mm. A 44.5 mm diameter inflation hole was cut in the center of the second 20 piece of fabric with six additional 6.5 mm diameter mounting holes located symmetrically around the inflation hole. The center of each mounting hole was about 65 mm from the edge of the inflation hole.

Two airbags were made by laying the first, smaller diameter piece of fabric on top of the larger diameter piece of fabric and aligning the centers of each piece. 25 The top piece of fabric was rotated such that the weave of the top piece was about 45° offset from the weave of the bottom piece. The fabric pieces were oriented such that the silicone coated side faced the inside of the restraint. Seams having a lap-shear geometry were formed by first cutting the larger diameter piece of fabric in each corner up to the overlaid smaller diameter fabric and forming tabs about

12.7 mm wide. The tabs were then folded onto the smaller diameter fabric and attached by sewing. Two rows of stitching were used to join the first and second pieces of fabric together. In one of the restraints, two 12.7 mm diameter vent holes were cut into the side of the restraint having the inflation hole. The vent hole were 5 about 75 mm from the center of the vent hole and 180 degrees apart.

Two more airbags were assembled in similar fashion as above, except the 10 seams were adhesively bonded in the following manner. A small amount of the catalyzed GE PSA529 adhesive (as described in Examples A-B above) was applied around the perimeter of each piece of fabric. The adhesive was allowed to dry for a few minutes and the 12.7 mm tabs were folded onto the first smaller diameter piece, and rolled with a 15 pound roller, forming seams having a lap-shear geometry. Two 15 12.7 mm diameter vent holes were cut into one of the adhesively-bonded restraints as described above. The adhesively-bonded fabrics were allowed to cure for one week at room temperature.

Each of the assembled restraints were then attached to a 37.9 L air tank pressurized to 620-655 kPa via an 85 mm diameter flange. A solenoid-actuated ball valve was actuated quickly (< 50ms) to simulate deployment conditions of the restraint. Inflation pressures were collected using a transducer and the maximum pressure obtained and the failure mode of each restraint was noted. Burst pressures 20 and failure modes for each of the cushions tested are shown in Table 2 below.

TABLE 2

Ex.	Fabric Type	Chamber Style	Seam Attachment Means	Maximum Pressure (kPa)	Failure Mode
C	PFG 64318	Octagon (vented)	Sewn	108.8	FT
D	PFG 64318	Octagon	Sewn	96.5	FT
E	PFG 64318	Octagon (vented)	GE PSA529	36.8	SF
F	PFG 64318	Octagon	GE PSA529	96.5	FT

25 Subsequent to the airbag tests of TABLE 2, inflatable restraints have been fabricated using the catalyzed GE PSA529 adhesive and successfully deployed

under real life conditions. The adhesives used in the below described examples, other than the catalyzed GE PSA529, have not been used to fabricate and deploy an inflatable restraint. Based on the below tabulated test results, it is believed that these other adhesives will perform as well or better than the cured GE PSA529.

5        Each of the shear strength values in TABLE 3, below, is an average of 3 to 5 samples tensile tested in shear. Tensile testing was all done on an Instron machine, with a 1000 lb (4448 N) load cell, at a rate of 12"/min. (30.48 cm/min.), and a 3" (7.62cm) gage length on 1" (2.54cm) wide adhesively bonded sample strips. The test samples used to generate the shear strength test results in TABLE 3  
10      were made using 420 denier nylon fabric manufactured by Milliken & Co. of Lagrange, Georgia, except for the samples of Example 28, which were made with an approximately 520 denier blue colored nylon fabric obtained from TRW. Unless otherwise indicated, the samples for the Examples in the TABLE 3 were prepared by applying the liquid adhesives with a foam applicator in an amount to visually and  
15      evenly cover the bond area. The two pieces that formed the bonded seam were put together right after they were coated. (no drying or curing [open] time was used for these samples). Unless otherwise indicated, after the coated surfaces were overlapped, pressure was applied from a hand held roller to form an overlapping seam; and each test sample was then allowed to stand for about 7 days before being  
20      tensile (shear) tested. As indicated in TABLE 3, these test samples were made from uncoated nylon fabric and nylon fabric having one side coated with silicone. In TABLE 3, the designations Si-Si, Ny-Si and Ny-Ny correspond, respectively, to samples of the silicone coated fabric strips where the overlapping surfaces being bonded are both coated (i.e., silicone to silicone), have one coated and one  
25      uncoated (silicone to nylon), and are both uncoated (nylon to nylon).

**TABLE 3**

Example	Uncoated Nylon Shear Strength (Psi/kPa)	Coated Nylon Shear Strength (Psi/kPa)		
		Si-Si	Ny-Si	Ny-Ny
1	76.5/527.5	183.7*/1266.6	99.8/688.1	107.6/741.9
2	106.3/732.9	207.3*/1429.3	107.7/742.6	77.0/530.9
3	100.6/693.6	212.6/1465.8	114.8/791.5	95.7/659.8
4	77.1/531.6	162.4/1119.7	94.0/648.1	90.1/621.2
5	98.6/679.8	138.2/952.9	101.7/701.2	97.6/672.9
6	78.1/538.5	128.1/883.2	112.3/774.3	103.3/712.2
7	82.5/568.8	147.1/1014.2	63.4/437.1	105.2/725.3
8	102.5/706.7	152.6/1052.1	123.6/852.2	117.9/812.9
9	80.8/557.1	90.1/621.2	66.3/457.1	108.4/747.4
10	104.1/717.7	214.6*/1479.6	117.0/806.7	127.1/876.3
11	71.0/489.5	174.4*/1202.5	112.1/772.9	93.5/644.7
12	102.3/705.3	186.6/1286.6	100.3/691.5	121.4/837.0
13	120.2/828.8	195.9*/1350.7	123.4/850.8	138.5/954.9
14	154.7/1066.6	193.0*/1330.7	166.2/1145.9	166.8/1150.1
15	132.7/914.9	204.9*/1412.7	129.7/894.3	131.5/906.7
16	89.2/615.0	186.2*/1283.8	115.3/795.0	49.9/344.1
17	84.1/579.9	190.2/1311.4	149.6/1031.5	112.9/778.4
18	67.7/466.8	195.9*/1350.7	106.6/735.0	134.7/928.7
19	72.2/497.8	149.0/1027.3	113.8/784.6	100.9/695.7
20	102.5/706.7	172.5/1189.4	109.5/755.0	97.3/670.9
21	103.4/712.9	153.1/1055.6	116.7/804.6	110.9/764.6
22	187.4/1292.1	193.4*/1333.5	201.4/1388.6	206.2/1421.7
23	ND	199.1*/1372.8	188.0*/1296.2	186.4/1285.2
24	171.8*/1184.5	209.3*/1443.1	201.8*/1391.4	179.7/1239.0
25	67.1/462.6	178.0*/1227.3	106.8/736.4	67.9/468.2
26	154.6/1065.9	227.2*/1566.5	142.3/981.1	161.7/1114.9
27	233.0*/1606.5	207.5*/1430.7	238.5*/1644.4	295.1*/2034.7
28	ND	259.0/1785.8	165.0/1137.6	ND
29	236.2*/1628.6	171.2/1180.4	149.2/1028.7	201.1/1386.5
30	206.8/1425.8	201.9/1392.1	194.1/1338.3	167.8/1156.9
31	65.2/449.5	205.6*/1417.6	159.4/1099.0	120.5/830.8
32	78.5/541.2	230.1*/1586.5	191.9/1323.1	149.1/1028.0
33	0	117.4/809.4	90.2/621.9	53.6/369.6
34	24.3/167.5	146.1/1007.3	95.7/659.8	118.8/819.1
35	11.7/80.7	119.1/821.2	111.2/766.7	104.2/718.4
<b>Uncoated Nylon</b>		257.0*/1772.0		
<b>Si-Coated Nylon</b>		256.7*/1769.9		

\* - indicates that at least one of the samples being averaged failed by the fabric tearing rather than the seam giving, as is usually the case.

**Examples 1-9**

The adhesives of Examples 1-9 are condensation cure-type pressure sensitive adhesives (PSA), where the components of each adhesive were blended at room temperature and mixed in the laboratory. Each of these exemplary adhesives 5 contains a silicone-based polymer gum having condensation curable functional groups, an MQ resin containing condensation curable functional groups, toluene, and the multi-functional crosslinker aminosilane manufactured by OSI Specialties of Danbury, CT, under the product designation Silquest A-1100. For each of these Examples 1-9, a batch of the silicone gum, MQ resin and toluene are first blended 10 together. Next, 6 parts of the A-1100 aminosilane, per 100 parts of solid polymer, is mixed with whatever amount of the resulting polymer gum blend is needed to make the desired number of samples. The resulting adhesive solution is applied to sample strips of the Milliken 420 denier nylon fabric, before any significant degree of curing of the adhesive occurs, to make the overlapping seam test samples.

15 Examples 1-3 were made using the low molecular weight (peak average molecular weight of 159,000 as determined by gel permeation chromatography) silicone polymer gum manufactured by Petrarch Systems, Inc., of Levittown, PA, under the product designation PS 199.5. Petrarch Systems, Inc., became Huls America, Inc., of Piscataway, NJ, which became Gelest, Inc., of Tullytown, PA.

20 For the Examples 4-6, the silicone polymer gum was a medium molecular weight gum (peak average molecular weight of 428,000 as determined by gel permeation chromatography) manufactured by GE Silicones under the product designation GE 1048-374, lot GE001. For Examples 7-9, the silicone polymer gum was a high molecular weight gum (peak average molecular weight of 604,000 as determined by 25 gel permeation chromatography) manufactured by GE Silicones under the product designation GE 1048-373, lot KC315. The MQ resin used for all of Examples 1-9 was SR545 resin solution (60 wt% solids in toluene) manufactured by GE Silicones of Waterford, New York. The amounts of polymer gum, MQ resin, and toluene used to form the adhesive solution for each of Examples 1-9 are listed in grams in 30 TABLE 4 below.

The Examples 1-9 illustrate the effect of silicone polymer molecular weight, MQ resin concentration and cross-link density on shear strength.

**TABLE 4**

Example	Silicone Gum (g)	MQ Resin Solution (g)	Toluene (g)
1	25	48.3	27.2
2	25	65.9	29.7
3	25	92.3	33.4
4	25	48.3	27.2
5	25	65.9	29.7
6	25	92.3	33.4
7	25	48.3	27.2
8	25	65.9	29.7
9	25	92.3	33.4

5 **Examples 10-15**

Commercially available solvent based pressure sensitive adhesive were each mixed with 6 parts of the A-1100 aminosilane cross-linking agent, per 100 parts of adhesive solids. After the liquid PSA and aminosilane were mixed, the resulting condensation cure silicone adhesives were each used to make tensile (shear) 10 samples as described above for Examples 1-9. For Examples 10, 11, 12, and 13, the silicone PSAs used were manufactured by Dow Corning under the product designations Q2-7406, 280A, 282 and Q2-7735, respectively. For Examples 14 and 15, the silicone PSAs used were manufactured by General Electric under the product designations 6573A and 529, respectively. These silicone PSAs were all 15 received in solution.

**Examples 16-21**

In each of the Examples 16-21, a condensation cure-type silicone adhesive was prepared by blending a pressure sensitive silicone adhesive solution with a 20 solution of an MQ resin in the proportions by weight (grams) indicated in TABLE 5, below. A desired amount of the resulting polymer blend was mixed with

6 parts of the A-1100 aminosilane cross-linking agent, per 100 parts of adhesive solids. This mixture was then used to make tensile test samples as described above for Examples 1-9. The silicone PSA solution used for Examples 16 and 17 was the Dow Corning PSA (received in solution) Q2-7406. The Dow Corning silicone PSA 5 solution 280A was used for Examples 18 and 19, and the Dow Corning silicone PSA solution 282 was used for Examples 20 and 21. The MQ resin solution used for Examples 16-21 was made by adding 10.9 parts toluene to 120 parts GE SR545. The GE SR545 resin was added to increase the total MQ resin content of the resulting adhesive in an effort to improve the cohesive (shear) strength of the 10 adhesive bond.

**TABLE 5**

<b>Example</b>	<b>PSA Solution (g)</b>	<b>MQ Resin Solution (g)</b>
16	50	14.3
17	50	30.4
18	50	14.3
19	50	30.4
20	50	10.2
21	50	25.5

**Examples 22-28**

15 Each of the samples in Examples 22, 23 and 28 were bonded with a room temperature vulcanizing (RTV) silicone adhesive. The General Electric neutral cure RTV167 and the Dow Corning neutral cure RTV3145 MIL-A-46146 were used to bond the tensile test samples for Examples 22 and 23, respectively. The tensile test samples of Examples 22 and 23 were made as described above for Examples 1-9 20 except after the adhesive was coated onto each fabric strip and the strips bonded together, the resulting samples were placed for 3 of the 7 days at 50°C in a forced air oven. A consumer silicone RTV caulk/sealant marketed under the name Cling n' Seal was used to bond the test samples of Example 28. The Cling'n Seal brand RTV silicone adhesive sealant came from the ITW Fluid Products Group,

Stock # 50050. These samples were not baked but simply stored at room temperature for 7 days before being tested.

Each of the Examples 24-27 used a thermal addition-cure (hydrosilation) silicone adhesive. The General Electric one-part silicone adhesives RTV6424, 5 RTV6445 and TSE 322 were used for Examples 24, 25 and 26, respectively, and the Dow Corning two-part silicone adhesive Sylgard 577 was used for Example 27. One percent by weight of the adhesion promoter glycidoxypipyltrimethoxy silane (GPTS) was mixed with the General Electric TSE 322 adhesive before being used to bond the test samples of Example 26. The addition of 1 percent by weight of this 10 adhesion promoter to the adhesives of Examples 24, 25, and 27 did not appear to result in an improvement in sample shear strength. Therefore, test data from such samples was not included herein. The test samples for Examples 24-26 (GE RTV6424, RTV6445, and TSE 322) were cured for 30 minutes at 150°C, and then stored at room temperature for seven days before being tested. The samples for 15 Example 27 (DC Sylgard 577) were cured for 60 minutes at 150°C, and then stored at room temperature for seven days before being tested.

### Examples 29 and 30

Both of the adhesives used to make the test samples for the Examples 29 20 and 30 are the silicone adhesive compositions disclosed in Examples 5 and 11, respectively, of the above incorporated co-pending U.S. patent application (U.S. Express Mail, Number TB895281035US), having the attorney Docket No. 53593USA6A.

For the samples of Example 29, polydimethylsiloxane polyurea segmented 25 copolymer adhesive solutions were made by combining 17 parts by weight of the below described polydimethylsiloxane polyurea segmented copolymers, 25.5 part by weight of the MQ resin SR1000, and 22.9 part by weight of a 50/50 toluene/2-propanol solvent mixture. These components were mixed until homogeneous. The adhesives were knife coated on 2 mil (.0508mm) PET release liner (Take-Off™ 30 available from Rexam Release, Iowa City, Iowa), dried 15 minutes at room temp followed by 15 minutes at 70°C to obtain dry films of approximately 5 mil (0.127mm) thickness. Overlap shear samples were then prepared by hot pressing

the adhesive film between test strips of the sample fabric. The polydimethylsiloxane polyurea segmented copolymer for the Example 29 adhesive was made in the following manner. Silicone diamine, Mn = 5,320, was fed at a rate of 289 g/min into zone 8 of a Berstorff 40mm screw diameter, 40 L/D (length to diameter ratio), 5 co-rotating, twin screw extruder. Tetramethylene-m-xylylene diisocyanate, obtained from Cytek Industries (West Paterson NJ) and used as received, was injected at a rate of 13.3 g/min into zone 9. The screws were fully intermeshing, rotating at a rate of 200 revolutions per minute. The temperature profile of the extruder was: zones 1 through 7 (not used), zone 8 120°C, zones 9, 10, endcap, 10 and melt pump 180°C. The resulting material was extruded through a strand die, quenched, and pelletized. This polydimethylsiloxane polyurea segmented copolymer was made in a manner similar to Example 23 of the above incorporated PCT Application No. PCT/US96/05869 (WO96/34029).

For the samples of Example 30, polydimethylsiloxane polyurea segmented copolymer adhesive solutions were made in the same manner as described for Example 29 except that 20 parts by weight of the below described polydimethylsiloxane polyurea segmented copolymer was combined with 46.7 parts by weight of the MQ resin SR1000 and 35.9 parts by weight of the 50/50 toluene/2-propanol solvent mixture. The polydimethylsiloxane polyurea segmented copolymer used in the Example 30 adhesive was made in the following manner. To a round bottom flask fitted with mechanical stirrer and static nitrogen atmosphere was added 100 pt of an aminopropyl terminated polydimethylsiloxane polymer (polydimethylsiloxane diamine) having molecular weight of 10,610. With mechanical agitation the contents of the flask were heated under aspirator vacuum 20 to 110°C, allowed to degas 15 minutes, and cooled under static nitrogen atmosphere to 80°C before 287 pt of 50/50 toluene/2-propanol were added. With the flask maintained at 50°C a solution containing 2.3 pt tetramethylene-m-xylylene diisocyanate and 20 pt of 50/50 toluene/2-propanol was added and stirring 25 continued for 16 hours to complete the reaction. The resulting clear viscous 30 solution was poured into a pan lined with release liner and allowed to dry under ambient conditions to provide a sheet of material.

It is believed that such adhesives containing amounts of copolymer and MQ resin in between the copolymer and MQ resin ratios used in Examples 29 and 30 would work well also.

5    **Examples 31 and 32**

In Example 31, a moisture cure silicone adhesive was prepared as follows. To a glass jar purged with argon was added 50 parts polydimethylsiloxane diamine, molecular weight 10,412, that had been degassed at 100°C for 5 minutes under high vacuum, and 2.38 parts 3-isocyanatopropyltriethoxysilane (available from Silar 10 Laboratories, Scotia, NY). The jar was capped and mixed slowly for 16 hours before 116.7 parts SR1000 MQ resin and 77.8 parts toluene were added and mixed to provide a homogenous adhesive solution. Aminopropyltriethoxysilane was added to this solution to provide 6 parts silane per 100 parts adhesive solids.

In Example 32, a moisture curable tackified polydimethylsiloxane oligourethane 15 segmented copolymer adhesive was prepared as follows. To a flask fit with mechanical stirrer, pressure-equalizing addition funnel, and positive argon atmosphere was added 50 parts of the degassed polydimethylsiloxane diamine of Example 31 and 50 parts toluene. In an argon purged vial a solution of 1.19 parts 3-isocyanatopropyltriethoxysilane, 0.63 parts methylenedicyclohexylene-4,4'-diisocyanate, and 25 parts toluene was prepared, charged to the addition funnel, and added slowly to the stirred flask. At the conclusion of the isocyanate addition the vial and addition-funnel were washed with a total of 25 parts toluene to introduce the last traces of the isocyanate charge to the flask. The flask contents stirred overnight to complete the preparation of the polydimethylsiloxane oligourethane 20 segmented copolymer solution. In a glass jar 145.8 parts copolymer solution and 114.6 parts SR1000 MQ resin were mixed to provide a homogeneous polydimethylsiloxane oligourethane segmented copolymer adhesive solution. Aminopropyltriethoxysilane was added to the adhesive solution to provide 6 parts silane per 100 parts adhesive solids.

**Examples 33-35**

In Example 33, a free-radically curable tackified polydimethylsiloxane oligourea segmented copolymer adhesive was prepared using the procedure of Example 32 with the following exceptions. The solution of isocyanates added to 5 the silicone diamine solution consisted of 0.74 parts isocyanatoethyl methacrylate (available as MOI from Showa Rhodia Chemicals, Tokyo, Japan), 0.63 parts methylenedicyclohexylene-4,4'-diisocyanate, and 25 parts toluene. The adhesive was prepared by mixing 145.6 parts polydimethylsiloxane oligourea segmented copolymer solution, 114.5 parts SR1000 MQ resin, and 6.54 parts of a 50% 10 solution of 2,4-dichlorobenzoyl peroxide in silicone fluid (Perkadox PD-50S-ps-a available from Akzo Nobel Chemicals Inc. Chicago, IL).

In Example 34, a free-radically curable tackified polydimethylsiloxane oligourea segmented copolymer adhesive was prepared using the procedure and amounts of Example 33, with the exception that 4-methyl-2-pentanone was 15 substituted for toluene.

In Example 35, a free radically curable silicone adhesive was prepared as follows. To a two-necked flask fit with mechanical stirrer and air drying tube was added 168.9 parts polydimethylsiloxane diamine, molecular weight 11,628. The silicone diamine was degassed at 100°C for 5 minutes under high vacuum and 20 cooled to ambient temperature before 4.5 parts isocyanatoethyl methacrylate (available as MOI from Showa Rhodia Chemicals, Tokyo, Japan) was added to the stirred silicone diamine solution. Slow stirring continued overnight to provide a methacrylate terminated polydimethylsiloxane polymer. To a glass jar was charged 50 parts of the methacrylate terminated polydimethylsiloxane polymer, 116.7 parts 25 SR1000 MQ resin, 6.66 parts of a 50% solution of 2,4-dichlorobenzoyl peroxide in silicone fluid (Perkadox PD-50S-ps-a available from Akzo Nobel Chemicals Inc. Chicago, IL), and 77.8 parts toluene.

The samples for Examples 33-35 were prepared by putting the bonded samples into a 340 °F heated press for 30 minutes at 5000 psi, but the plates were 30 shimmed so as not to squeeze adhesive beyond the desired bonding area. The "sandwich" thickness was 28 mils for the adhesive seam and fabric (fabric is about

12.5 mils thick for each sheet), 6 mils each for the two sheets of silicone-coated fiberglass, and two sheets of aluminum at 25 mils each. That would give us 0.020" difference between the "sandwich" and the shims.

5    **Examples 36 and 37**

The test samples for Examples 36 and 37 were strips of the uncoated and silicone coated 420 Denier Nylon fabric, respectively, manufactured by Milliken & Co.. These Examples provide the strength of the fabric as a reference.

10       The invention may further be illustrated by the following Example of an adhesive tape.

**Tape Example**

15       Uncoated white 420 denier, 47X47 weave, nylon fabric from Milliken & Co., of Spartanburg, South Carolina, was used as the backing for the adhesive tape. A silicone-coated fabric would also be suitable. A two-inch wide tape was prepared. A two-inch wide tape would give a one-inch wide seal on both sides of a butt joint seam application. The adhesive solution of Example 5 below was coated onto an HP Smith DR314 fluorosilicone liner (6" wide) using a knife coater and 20 dried at room temperature for 15 minutes, followed by exposure in a 66°C forced air oven to yield a non-tacky adhesive film about 6 mils thick.

25       Work with this adhesive and the uncoated Milliken 420 denier fabric backing showed that when the adhesive was heat pressed onto the fabric backing, good shear strength could be obtained in standard one-inch wide strip tensile and elongation testing of fabric-to-fabric bonds using an Instron™ machine. It was determined that this adhesive could be applied to the fabric backing, then the liner could be removed by hand without the need for heat pressing. The fabric backed adhesive could then be bonded to another piece of fabric using a heat press at 160°C for 60 seconds at about 5,000 PSI (34.5 MPa) pressure. The press was 30 shimmed to about 0.079"-0.082" (about 2.01-2.08 mm) so that the bond was only seeing heat and not pressure in order to avoid oozing of the adhesive past the desired bond line.

An 18" (45.7cm) long piece of backed adhesive tape was prepared using the uncoated Milliken fabric. A 20" (50.8cm) long and 2" (5.08cm) wide piece of the hand spread adhesive, dried on the liner, was cut out and applied to a two-inch wide strip of the 420 denier nylon. With the liner still on the adhesive, the

5      fabric/adhesive/liner combination was heat pressed as described above. The nylon and the adhesive were set between two silicone-coated fiberglass sheets and then between two 0.013" (.33mm) thick aluminum sheets for the pressing. The thickness of the "sandwich" going into the press was approximately 0.062" (1.57mm), giving a difference of about 0.017"-.020" (0.43mm-0.51mm)) between the sandwich and

10     the shims (as described above).

After pressing, the 18" (45.7cm) long strip of the resulting adhesive tape had a good appearance, minimal curl, and the liner came off easily. The adhesive bonded well to the fabric backing, and it was non-tacky to the touch. The resulting backed adhesive tape appeared to be able to be rolled up onto itself without

15     blocking.

As an alternative to the above tape forming process, such a solvent cast adhesive layer, or an extruded adhesive layer, can be laminated onto the fabric backing using heated pressure rollers. For example, the adhesive layer, its release liner and the fabric backing were sandwiched together between two pieces of

20     silicone coated fiberglass fabric so that the adhesive layer is sandwiched between the release liner and the fabric backing. The silicone coatings contact the release liner and the fabric backing. The resulting layered construction was run through a pair of pressure rollers, having a length of about 25.5 inches (64.8cm) and an overall diameter of about 1.5 inches (3.81cm). The diameter of each roller includes

25     about a 0.5 inch (1.27cm) thick layer of rubber having a Shore A durometer of 55-60. The layered construction was processed through the pressure rollers at a rate of about 10 feet/min. (3.05m/min.). The rollers were heated using convection heaters set at a temperature in the range of about 149°C to about 190°C. The rollers were gapped so as to apply enough pressure, with the applied heat, to

30     adequately activate the adhesive and laminate or bond the adhesive to the fabric backing.

Below are examples of silicone adhesives of the type that contain a silicone-urea segmented copolymer and an MQ silicate resin. The following polydiorganosiloxane polyurea segmented copolymers were prepared by either a solvent based process or by a solventless (e.g., extrusion) process as described 5 below. All polyisocyanates were used as received and the polyisocyanate:polyamine ratios were calculated using the polyisocyanate molecular weight reported by the polyisocyanate supplier and the polydiorganosiloxane diamine molecular weight as determined by acid titration.

10 **Polydimethylsiloxane Polyurea Segmented Copolymer A**

A polydimethylsiloxane polyurea segmented copolymer was made in the following manner. Tetramethylene-m-xylylene diisocyanate, obtained from Cytek Industries (West Paterson, New Jersey) and used as received, was fed into zone 1 of a Leistritz 18mm screw diameter, 40 L/D (length to diameter ratio), co-rotating, 15 twin screw extruder at a rate of 0.737 g/min. Silicone diamine, Mn = 2,630 (Huls America, Inc. PS 510, lot 135,116), was injected at a rate of 7.9 g/min into zone 2. The screws were fully intermeshing, rotating at a rate of 40 revolutions per minute. The temperature profile of the extruder was: zone 1: 60°C, zone 2: 120°C, zone 3: 130°C, zone 4: 140°C, zone 5: 150°C, zone 6: 155°C, and zones 7 and 8: 170°C. 20 The resulting material was extruded through a strand die, quenched, and pelletized. This polydimethylsiloxane polyurea segmented copolymer was made in a manner similar to Example 22 in the above incorporated PCT Application No. PCT/US96/05869 (Publication No. WO96/34029).

25 **Polydimethylsiloxane Polyurea Segmented Copolymer B**

A polydimethylsiloxane polyurea segmented copolymer was made in the following manner. Silicone diamine, Mn = 5,320, was fed at a rate of 289 g/min into zone 8 of a Berstorff 40mm screw diameter, 40 L/D (length to diameter ratio), co-rotating, twin screw extruder. Tetramethylene-m-xylylene diisocyanate, 30 obtained from Cytek Industries (West Paterson NJ) and used as received, was injected at a rate of 13.3 g/min into zone 9. The screws were fully intermeshing.

rotating at a rate of 200 revolutions per minute. The temperature profile of the extruder was: zones 1 through 7 (not used), zone 8 120°C, zones 9, 10, endcap, and melt pump 180°C. The resulting material was extruded through a strand die, quenched, and pelletized. This polydimethylsiloxane polyurea segmented copolymer was made in a manner similar to Example 23 of the above incorporated PCT Application No. PCT/US96/05869 (WO96/34029).

#### Polydimethylsiloxane Polyurea Segmented Copolymer C

A polydimethylsiloxane polyurea segmented copolymer was made in the following manner. To a round bottom flask fitted with mechanical stirrer and static nitrogen atmosphere was added 100 pt of a polydimethylsiloxane diamine having molecular weight of 10,610. With mechanical agitation the contents of the flask were heated under aspirator vacuum to 110°C, allowed to degas 15 minutes, and cooled under static nitrogen atmosphere to 80°C before 287 pt of 50/50 toluene/2-propanol were added. With the flask maintained at 50°C a solution containing 2.3 pt tetramethylene-m-xylylene diisocyanate and 20 pt of 50/50 toluene/2-propanol was added and stirring continued for 16 hours to complete the reaction. The resulting clear viscous solution was poured into a pan lined with release liner and allowed to dry under ambient conditions to provide a sheet of material.

20

#### Polydimethylsiloxane Polyurea Segmented Copolymer D

A polydimethylsiloxane polyurea segmented copolymer was made in the same manner as Polydimethylsiloxane Polyurea Segmented Copolymer C except that the following reactant charges were employed, 3.83 pt silicone diamine, Mn = 11,784, 6.17 pt silicone diamine, Mn = 17,000, and 0.168 pt tetramethylene-m-xylylene.

#### Overlap Shear Sample Preparation and Testing

Sample preparation for overlap shear testing is dependent on the form of the adhesive used, i.e., solid film adhesive, liquid adhesive, or paste adhesive. The preparation of an exemplary solid film adhesive overlap shear test sample is

30

described below. In all cases samples constructed had an overlap shear area of about 2.54 cm<sup>2</sup>.

In the case of a solid film adhesive, a 2.54 cm x 17.8 cm strip of film adhesive on release liner was placed adhesive side down on a 12.7 cm x 17.8 cm 5 piece of test fabric, the long dimension of the test fabric being in the cross web direction unless otherwise noted, such that the long dimension of the adhesive film was located directly atop and adjacent to the edge of the long dimension of the fabric. The release liner was removed and a second piece of the same fabric having identical dimensions was placed on top of the adhesive strip to create an overlap 10 shear sample having an overlap area of 2.54 cm. The sample was placed between two 6 mil thick siliconized glass cloth sheets backed with 12 mil thick aluminum sheets. The overlap shear construction was placed in a shimmed platen press at 160°C for 60 seconds to provide an overlap shear sample having a final bond thickness of about 3-4 mils (.0762mm-.102mm). Finished samples stood for 3-4 15 days at ambient condition before being cut into seven 2.54 cm x 17.8 cm strips. Each sample was mounted in an H-frame style testing machine, manufactured by Instron Corp, Canton, Massachusetts, at a gauge height of 7.6 cm and pulled at a crosshead speed of 30.5 cm/min. The average of five individual tests is reported as the overlap shear strength.

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#### Adhesive Examples 38-54

Polydimethylsiloxane polyurea segmented copolymer adhesive solutions were made by combining polydimethylsiloxane polyurea segmented copolymers, MQ resin, and 50/50 toluene/2-propanol in the ratios shown in TABLE 6 and 25 mixing until homogeneous. All amounts are in parts by weight, unless indicated otherwise. The adhesives were knife coated on 2 mil (.0508mm) PET release liner (Take-Off™ available from Rexam Release, Iowa City, Iowa), dried 15 minutes at room temp followed by 15 minutes at 70°C to obtain dry films of approximately 5 mil (0.127mm) thickness. Overlap shear testing samples were prepared using a 30 nylon fabric available from Precision Fabrics Group, Inc., Greensboro, North Carolina of about 300 denier weight coated with silicone on one side. Overlap shear

samples were prepared and tested as described previously with the exceptions that the long dimension of the nylon fabric sheet was in the machine direction and the bond was created between the silicone coated side of the fabric and the uncoated side of the fabric. Results are reported below in TABLE 6.

5

**TABLE 6**

Example	Segmented Copolymer	Segmented Copolymer (Parts)	SR1000 MQ (Parts)	Solvent (Parts)	Overlap Shear Strength (psi/kPa)
38	A	17	20.8	20.3	44.5/307
39	A	17	25.5	22.9	31.9/220
40	A	17	31.6	26.2	21.7/150
41	B	17	20.8	20.3	141/972
42	B	17	25.5	22.9	152/1048
43	B	17	31.6	26.2	128/883
44	B	10	30	21.5	28.2/194
45	B	10	40	26.9	*
46	C	20	20	21.5	92.4/637
47	C	20	30	26.9	121/834
48	C	20	46.7	35.9	161/1110
49	C	10	30	21.5	42.7/294
50	C	10	40	26.9	*
51	D	20	24.4	23.9	89/614
52	D	20	37.1	30.8	99.7/687
53	D	10	30	21.5	44.9/310
54	D	10	40	26.9	*

\* - adhesive too fragile to construct samples due to high silicate resin content.

#### 10 Adhesive Example 55

A polydimethylsiloxane polyurea segmented copolymer adhesive was made in the following manner. Silicone diamine, Mn = 5,304.5, was fed at a rate of 57.8 g/min into zone 1 of a Berstorff 40mm screw diameter, 40 L/D (length to diameter ratio), co-rotating, twin screw extruder. MQ silicone tackifying resin (GE

Silicones, SR1000, lot FJ500) used as received, was fed at a rate of 90.72 g/min into zone 2. Tetramethylene-m-xylylene diisocyanate, obtained from Cytek Industries (West Paterson, New Jersey) and used as received, was injected at a rate of 2.6317 g/min into zone 9. The screws were fully intermeshing, rotating at a rate of 350 revolutions per minute. The temperature profile of the extruder was: zone 1: 60°C, zones 2 through 10, endcap and melt pump: 170°C. The material was extruded through a strand die.

**Adhesive Example 56**

10 A polydimethylsiloxane polyurea segmented copolymer adhesive was made in the following manner. Silicone diamine, Mn = 10768, was fed at a rate of 22.74 g/min into zone 1 of a Berstorff 40mm diameter, 40 L/D (length to diameter ratio), co-rotating, twin screw extruder. TMXDI, obtained from Cytek Industries (West Paterson, NJ) and used as received, was injected at a rate of 0.5211 g/min into 15 zone 2. MQ silicone tackifying resin (GE Silicones, SR1000, lot FJ500) used as received, was fed at a rate of 52.97 g/min into zone 4. The screws were fully intermeshing, rotating at a rate of 300 revolutions per minute. The temperature profile of the extruder was: zone 1: 60°C, zone 2: 120°C, zones 3 through 10, endcap and melt pump: 170°C. The material was extruded through a strand die.

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**Adhesive Example 57**

25 The adhesive solution of Example 48 was used to create a hot-melt adhesive tape according to the following procedure. The adhesive solution was continuously applied, using a knife coater, to the polyethyleneterephthalate-based release film employed in Example 38, and passed through a three zone forced air oven having two 3.9 m zones and a final zone of 7.8 m, the three zones being at temperatures of 38°C, 49°C, and 66°C respectively, at a line speed of 1 m/min and wound up to provide a roll of hot-melt adhesive tape having an adhesive thickness of 2.5 mil (.0635mm). The tape roll was run through the same process again to overcoat the 30 first layer of adhesive with a second layer of adhesive and obtain an overall adhesive thickness of 5 mil (.127mm). This adhesive was used to create overlap shear

samples from two different 420 denier nylon fabrics available from Milliken & Company, Spartanburg, SC. Fabrics 1 and 2 were the same base fabric but fabric 2 was silicone coated on one side, thus the fabric had a nylon face and a silicone face. Fabric 2 was bonded together in three different fabric face orientations, nylon side to nylon side (N-N), nylon side to silicone coated side (N-S), silicone coated side to silicone coated side (S-S). Overlap shear samples were prepared using a one inch (2.54 cm) width strip of adhesive as described above, with the exception that in this case the silicone coated glass cloth was not backed with aluminum plates, and rather than pressing the samples in a heat press they were fed through a heat laminator set at 190°C at a speed of 3.9 m/min. Overlap shear strength (OLS) test results are presented in TABLE 7.

TABLE 7

Fabric	Fabric Faces Bonded	OLS (psi/kPa)
1	na	204.4/1409
2	S-S	201.3/1388
2	N-S	197.7/1363
2	N-N	245.9/1695

The use of an adhesive tape to bond a structural seam of an inflatable restraint eliminates the need to sew the seam together (a cumbersome, time consuming process that can also compromise the integrity of the inflatable restraint, as discussed above). In addition, employing a butt joint seam geometry eliminates the need to overlap portions of the fabric brought together to form the seam. Where overlap seams are used to form a structural seam, the use of an adhesive tape to bond the seam eliminates the need for a liquid adhesive. Eliminating the need for a liquid adhesive provides a more user friendly environment for fabricating inflatable restraints. The use of a tape to bond structural seams, or as described below, to reinforce inflator holes, vent holes, and the like, advantageously allows for the use of lighter weight fabrics; no sewing is required and the fabric will not be subject to combing upon deployment. The use of a tape to bond structural seams of

an inflatable restraint may offer additional applications and design options for inflatable restraint devices, and improve the ease of manufacture of such devices.

With the teachings of the present invention, various modifications and alterations to this invention will become apparent to those skilled in the art without departing from the scope and spirit of this invention. It should be understood that this invention is not intended to be limited by the embodiments and examples set forth herein and that such examples and embodiments are presented by way of example only with the scope of the invention intended to be limited only by the claims set forth herein as follows.

5

What is claimed is:

1. An inflatable restraint comprising:  
an inflatable chamber comprising at least one sheet of a material  
5 suitable for use in an inflatable restraint and one or more structural seams, each  
structural seam being formed by at least two edges of said at least one sheet, said  
inflatable chamber having a substantial portion of at least one structural seam  
bonded with an adhesive selected such that said at least one structural seam is  
capable of withstanding inflation forces resulting from deployment of said inflatable  
10 restraint, when said structural seam is bonded with said adhesive.
2. The inflatable restraint of claim 1, wherein said at least one structural  
seam has a lap shear geometry formed by said two edges overlapping each other so  
as to form overlapping portions of said at least one sheet, and said adhesive is  
15 disposed between said overlapping portions so as to bond said at least one  
structural seam.
3. The inflatable restraint of claim 1, wherein said adhesive is at least  
one silicone pressure-sensitive adhesive comprising a silicone base polymer and a  
20 silicate resin, said silicone base polymer comprising condensation curable functional  
groups, and said silicate resin containing condensation curable functional groups.
4. The inflatable restraint of claim 3, wherein said at least one silicone  
pressure-sensitive adhesive is at least one of a condensation cured pressure-sensitive  
25 adhesive and a peroxide cured pressure-sensitive adhesive, where said condensation  
cure pressure-sensitive adhesive further comprises a condensation curing agent and  
said peroxide cure pressure-sensitive adhesive further comprises a peroxide cross-  
linking agent.

5. The inflatable restraint of claim 3, wherein said silicone base polymer and said silicate resin are pre-condensed together prior to said at least one silicone pressure-sensitive adhesive being applied and fully condensation cured.

5 6. The inflatable restraint of claim 1, wherein said adhesive is at least one addition-cure silicone adhesive comprising an alkenyl functional silicone base polymer, a hydride functional cross-linking agent, and a hydrosilation catalyst.

10 7. The inflatable restraint of claim 6, wherein said at least one addition-cure silicone adhesive is an addition-cure silicone pressure-sensitive adhesive.

8. The inflatable restraint of claim 6, wherein said at least one addition-cure silicone adhesive is a room temperature vulcanizing adhesive.

15 9. The inflatable restraint of claim 1, wherein said adhesive is at least one free radical-cure silicone pressure-sensitive adhesive comprising an ethylenically unsaturated silicone base polymer, and a silicate resin.

20 10. The inflatable restraint of claim 1, wherein said adhesive is at least one silicone adhesive comprising a non-curable tackified polydiorganosiloxane polyurea segmented copolymer.

25 11. The inflatable restraint of claim 10, wherein said at least one silicone adhesive is selected from the group consisting of a pressure-sensitive adhesive, a heat activated pressure-sensitive adhesive, a non-tacky heat activated adhesive and a combination thereof.

30 12. The inflatable restraint of claim 1, wherein said adhesive is at least one silicone adhesive comprising a curable tackified polydiorganosiloxane oligourethane segmented copolymer.

13. The inflatable restraint of claim 12, wherein said at least one silicone adhesive is selected from the group consisting of a pressure-sensitive adhesive, a heat activated pressure-sensitive adhesive, a non-tacky heat activated adhesive and a combination thereof.

5

14. The inflatable restraint of claim 12, wherein said at least one silicone adhesive is selected from the group consisting of a free-radical cure adhesive, a moisture cure adhesive and a combination thereof.

10

15. The inflatable restraint of claim 1, wherein said adhesive is at least one moisture-cure room temperature vulcanizing silicone adhesive.

16. The inflatable restraint of claim 15, wherein said at least one silicone adhesive is a neutral-cure room temperature vulcanizing adhesive.

15

17. An inflatable protective device comprising:

a housing;

an inflation device attached to the housing; and

an inflatable restraint comprising an inflatable chamber having a

20 substantial portion of at least one structural seam bonded with an adhesive so as to have a lap-shear geometry, said adhesive being selected such that said at least one structural seam is capable of withstanding inflation forces resulting from deployment of said inflatable restraint, when said structural seam is bonded with said adhesive tape.

25

18. A method of making an adhesively-bonded inflatable restraint comprising the steps of:

providing an adhesive and at least one sheet of a material suitable for use in an inflatable restraint, the sheet having two edges;

30 overlapping the two edges of the sheet so as to form a seam having a lap shear geometry and to form at least part of an inflatable chamber;

disposing the adhesive between the overlapping edges of the sheet;  
and  
activating the adhesive so as to bond the overlapping edges together,  
wherein the adhesive is selected such that the seam is capable of  
5 withstanding inflation forces resulting from deployment of the inflatable restraint,  
when the overlapping edges are bonded with the adhesive.

19. The method of claim 18, wherein the adhesive being provided is a  
curable adhesive, said method includes the step of curing the adhesive after said  
10 step of activating the adhesive, and the resulting seam is capable of withstanding  
inflation forces resulting from deployment of the inflatable restraint, after the  
adhesive is substantially cured.

20. The method of claim 18, wherein the at least one sheet being  
15 provided is at least two sheets of a material suitable for use in an inflatable restraint,  
with each sheet providing one of the at least two edges.

21. The method of claim 18, wherein said step of disposing the adhesive  
between the overlapping edges of the sheet includes bonding the adhesive along at  
20 least one of the edges before said step of overlapping the two edges of the sheet.

22. An inflatable restraint comprising an inflatable chamber, said  
inflatable chamber comprising at least one sheet of a material suitable for use in an  
inflatable restraint and one or more structural seams, each structural seam being  
25 formed by at least two edges of said at least one sheet, said inflatable chamber  
having a substantial portion of at least one structural seam bonded with an adhesive  
tape,  
wherein said adhesive tape is selected such that said at least one structural  
seam is capable of withstanding inflation forces resulting from deployment of said  
30 inflatable restraint, when said structural seam is bonded with said adhesive tape.

23. The inflatable restraint of claim 22, wherein said tape comprises a backing having two major surfaces and an adhesive on at least one major surface, said backing and said adhesive being selected such that said at least one structural seam is capable of withstanding inflation forces resulting from deployment of said 5 inflatable restraint, when said structural seam is bonded with said tape.

24. The inflatable restraint of claim 23, wherein said at least one structural seam has a butt joint geometry formed by said two edges, and said tape overlaps said edges so as to bond said structural seam.

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25. The inflatable restraint of claim 23, wherein said adhesive is on both major surfaces, said at least one structural seam has a lap shear geometry formed by said two edges overlapping each other so as to form overlapping portions of said at least one sheet, and said tape is disposed between said overlapping portions so as to 15 bond said structural seam.

26. The inflatable restraint of claim 22, wherein said tape is an adhesive transfer tape comprising at least one adhesive layer without a backing, said adhesive layer being selected such that said at least one structural seam is capable of 20 withstanding inflation forces resulting from deployment of said inflatable restraint, when said structural seam is bonded with said tape.

27. The inflatable restraint of claim 26, wherein said at least one structural seam has a lap shear geometry formed by said two edges overlapping 25 each other so as to form overlapping portions of said at least one sheet, and said adhesive transfer tape is disposed between said overlapping portions so as to bond said structural seam.

28. The inflatable restraint of claim 22, wherein said adhesive is at least 30 one adhesive from the group consisting of a hot-melt type adhesive and a pressure-sensitive type adhesive.

29. The inflatable restraint of claim 28 wherein said adhesive comprises a silicone adhesive comprising a silicone-urea segmented copolymer and a silicate resin.

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30. The inflatable restraint of claim 22, wherein said inflatable chamber further comprises a retaining ring assembly, said retaining ring assembly comprises at least one retaining ring bonded about the periphery of an opening in said inflatable chamber by at least one adhesive layer.

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31. The inflatable restraint of claim 30, wherein said retaining ring and said at least one adhesive layer form a backed adhesive tape.

32. The inflatable restraint of claim 22, wherein said inflatable chamber further comprises a retaining ring assembly, said retaining ring assembly comprises at least one retaining ring bonded about the periphery of an opening in said inflatable chamber on an inner surface of said inflatable chamber, at least one other retaining ring bonded about the periphery of said opening on an outer surface of said inflatable chamber, and each said retaining ring being bonded using at least one layer of an adhesive.

33. The inflatable restraint of claim 22, wherein said inflatable chamber has two opposing inner surfaces, said inflatable restraint includes a tether having opposite ends and a length, each end of said tether is bonded to one of said opposing inner surfaces of said inflatable chamber with an adhesive layer so that said adhesive layer is subjected to substantially tensile loading, not peel loading, during the inflation of said inflatable chamber as said inflatable restraint is deployed, said adhesive layer is selected so as to withstand the inflation forces resulting from deployment of said inflatable restraint and maintain the bond between said tether and said opposing inner surfaces, and the length of said tether limits the separation of said opposing inner surfaces during the inflation of said inflatable chamber.

34. A tape useful for bonding a structural seam of an inflatable restraint, said tape comprising at least one adhesive layer selected such that when used to bond a structural seam of an inflatable restraint, the seam is capable of withstanding 5 inflation forces resulting from deployment of the inflatable restraint.

35. The tape of claim 34, wherein said at least one adhesive layer is self-supportive without a support backing.

10 36. The tape of claim 34, wherein said tape further comprises a backing having two major surfaces and at least one adhesive layer is on at least one major surface, said backing and said at least one adhesive layer being selected such that when used to bond a structural seam of an inflatable restraint, the seam is capable of withstanding inflation forces resulting from deployment of the inflatable restraint.

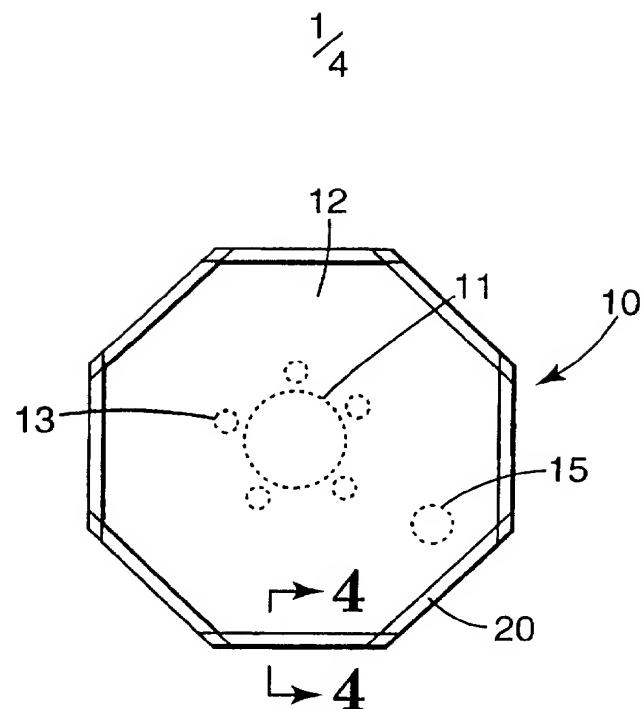
15 37. The tape of claim 34, wherein said at least one adhesive layer comprises at least one adhesive selected from the group consisting of a hot melt-type adhesive and a pressure sensitive-type adhesive.

20 38. The tape of claim 37, wherein said at least one adhesive layer comprises a silicone adhesive comprising a silicone-urea segmented copolymer and a silicate resin.

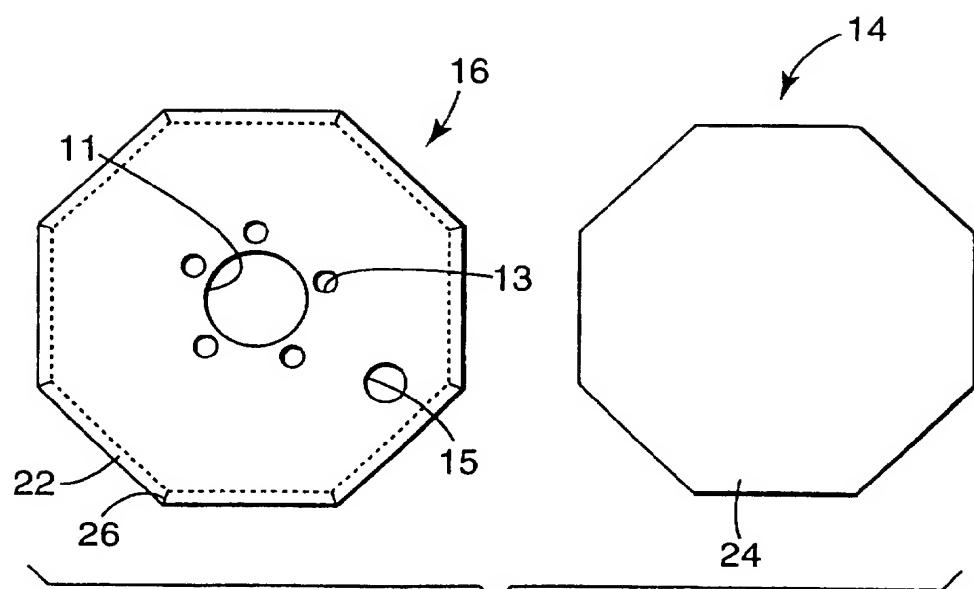
25 39. A method of making an inflatable restraint comprising the steps of: providing at least one sheet of a material suitable for making an inflatable restraint, with the at least one sheet having two edges, and an adhesive tape; forming the at least one sheet so as to define an inflatable chamber having at least one structural seam formed by the two edges; and 30 bonding a substantial portion of the at least one structural seam with the adhesive tape.

40. The method of claim 39, wherein the adhesive tape being provided is a backed adhesive tape, said forming step includes forming the at least one sheet so that the at least one structural seam has a butt joint geometry formed by the two 5 edges, and said bonding step includes applying the backed adhesive tape so as to overlap the edges and bond the structural seam.

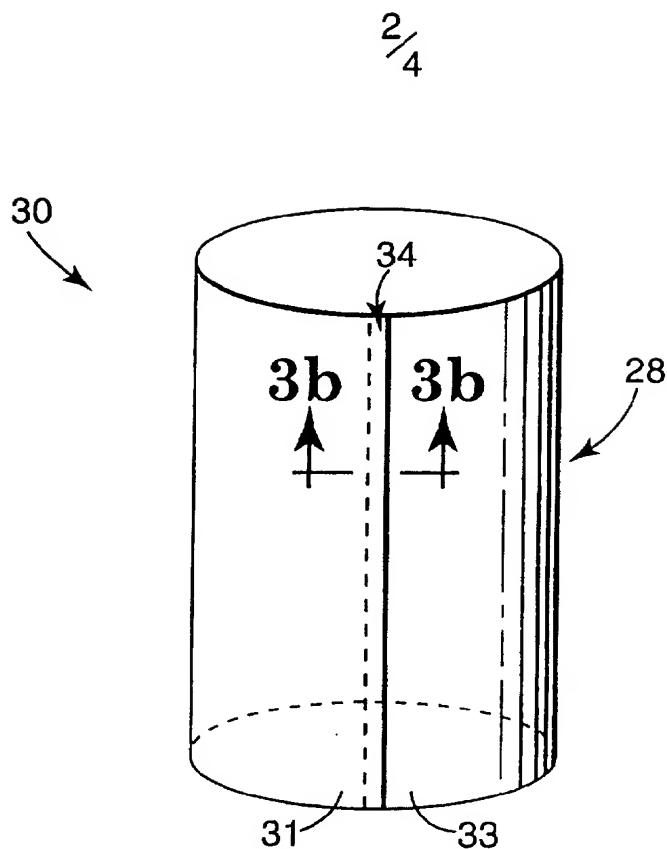
41. The method of claim 39, wherein said forming step includes forming the at least one sheet so that the at least one structural seam has a lap shear 10 geometry formed by the two edges overlapping each other so as to form overlapping portions of the at least one sheet, and said bonding step includes disposing the adhesive tape between the overlapping portions so as bond the structural seam.



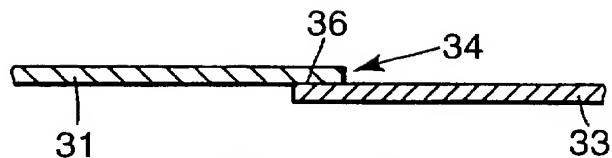
**Fig. 1**



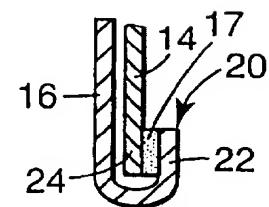
**Fig. 2**



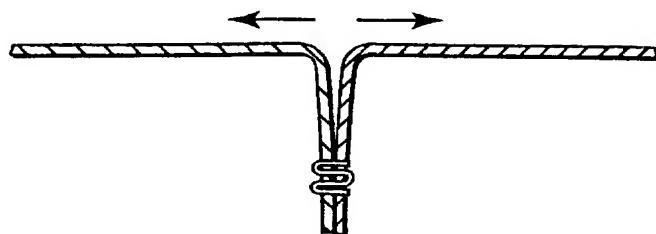
**Fig. 3a**



**Fig. 3b**



**Fig. 4**



**Fig. 5**

SUBSTITUTE SHEET (RULE 26)

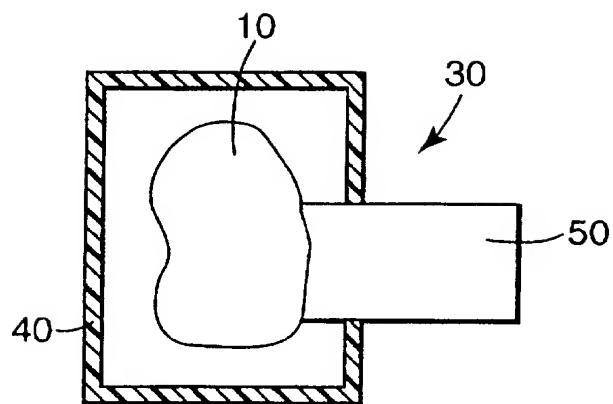
$\frac{3}{4}$ 

Fig. 6

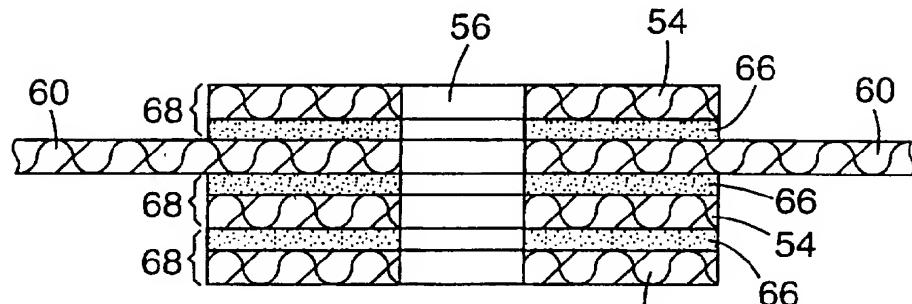


Fig. 7

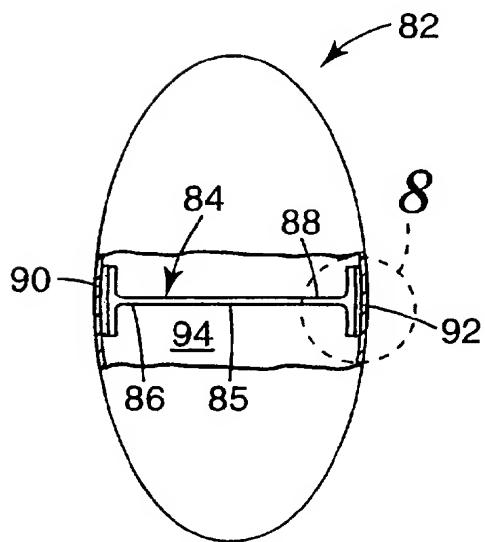


Fig. 8

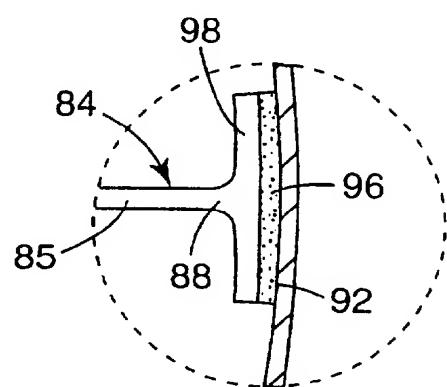


Fig. 9

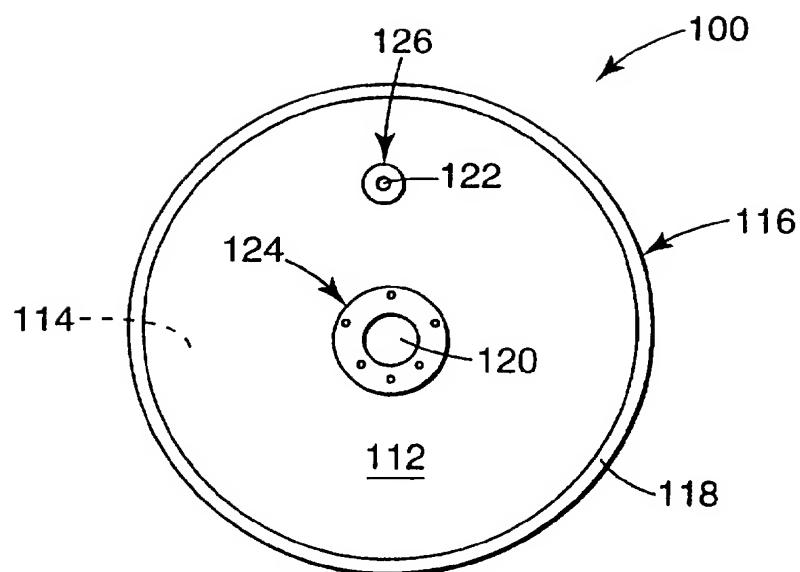


Fig. 10

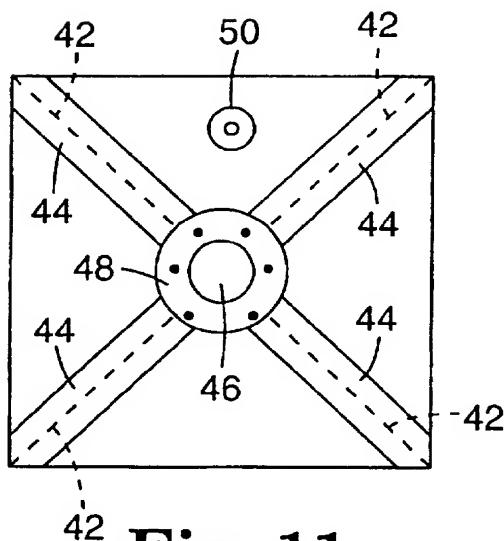


Fig. 11

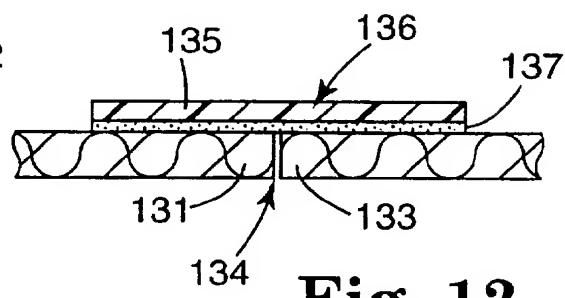


Fig. 12

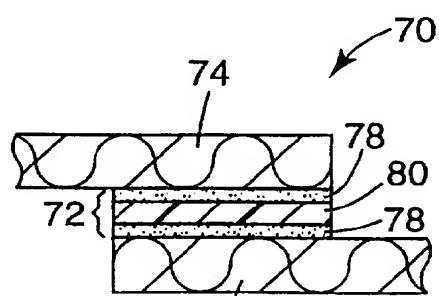


Fig. 13

SUBSTITUTE SHEET (RULE 26)

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 97/16543

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 6 B60R21/16

According to International Patent Classification(IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
IPC 6 B60R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 018, no. 220 (M-1595), 20 April 1994 & JP 06 016099 A (TOSHIBA SILICONE CO LTD), 25 January 1994, see abstract	1,2,17, 18,20,21
Y	---	22, 26-28, 30, 32-35, 37,39,41
Y	GB 998 232 A (DOW CORNING CORP.) 14 July 1965 cited in the application  see page 1, line 10 - line 30 see page 3, line 26 - line 55 ---	22-24, 26-28, 30, 32-37, 39-41
		-/-

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

° Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
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- "P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"g" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
7 January 1998	14/01/1998
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer  Dubois, B

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 97/16543

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	PATENT ABSTRACTS OF JAPAN vol. 017, no. 222 (M-1404), 7 May 1993 & JP 04 356249 A (ACHILLES CORP ET AL), 9 December 1992, see abstract ---	22-24, 28,34, 36,37, 39,40
X	PATENT ABSTRACTS OF JAPAN vol. 017, no. 222 (M-1404), 7 May 1993 & JP 04 356248 A (ACHILLES CORP ET AL), 9 December 1992, see abstract ---	1,2,17, 18,20,21
A	PATENT ABSTRACTS OF JAPAN vol. 014, no. 552 (M-1056), 7 December 1990 & JP 02 234863 A (TAKATA KK), 18 September 1990, see abstract ---	30
A	DE 43 06 696 A (PHOENIX AG) 16 September 1993 see column 1, line 3 - line 58; claims 1,2,4; figures 2,3 ---	33
A	US 5 482 317 A (NELSEN ET AL.) 9 January 1996 cited in the application see abstract see column 9, line 13 - column 10, line 17; figures 6,7,15,16 see column 10, line 55 - column 11, line 4 -----	22,23, 25,30, 33,34, 36,39

# INTERNATIONAL SEARCH REPORT

Information on patent family members

Int'l. Application No

PCT/US 97/16543

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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